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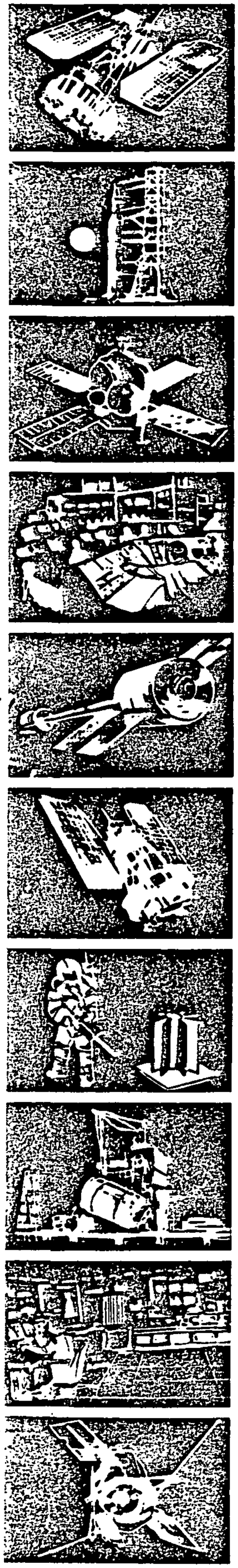

SHUTTLE/SPACELAB MMAP ELECTROMAGNETIC ENVIRONMENT EXPERIMENT

Phase B Definition Study Preliminary Report

GE Report No. 1J42-110

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16. Abstract

Results described in this report represent progress made in the first five months of the Phase B Definition Study for the MMAP/Electromagnetic Environment Experiment (EEE). An antenna/receiver assembly has been defined and sized for stowing in a three pallet bay area in the Shuttle. Six scanning modes for the assembly are analyzed and footprints for various antenna sizes are plotted. Mission profiles have been outlined for a 400 km height, 57° inclination angle, circular orbit. Viewing time over 7 geographical areas are listed. Shuttle interfaces have been studied to determine what configuration the antenna assembly must have to be shared with other experiments of the Microwave Multi-Applications Payload (MMAP) and to be stowed in the shuttle bay. The antennas will be shared with six experiments including EEE. Other results reported include a frequency plan, a proposed antenna subsystem design, a proposed receiver design, preliminary outlines of the experiment controls and an analysis of on-board and ground data processing schemes. An outline of the work planned for the next period is included.

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PREFACE

The National Aeronautics and Space Administration (NASA) has proposed a Shuttle/Spacelab Electromagnetic Environment Experiment (EEE) to measure and characterized earth-emitted, electromagnetic (interference) environment (EE) at frequencies allocated for space use, or potential space use, over the frequency range of 0.4 to 40 GHz. Since radio frequency (RF) spectrum occupancy is experiencing an exponential growth, an object of this experiment is to establish a capability of continuous RF spectrum monitoring and electromagnetic environment mapping from space. This report includes the results achieved during the first five months of the EEE Phase B System Definition Study. A proposed antenna subsystem that is shared by six experiments, a proposed receiver subsystem, preliminary outlines for experiment controls, and an analysis of on-board and ground data processing have been completed. The antenna subsystem has been sized to stow in a three-pallet area in the Shuttle bay. A typical Shuttle mission profile has been analyzed for a 400 km, 57° inclination, circular orbit. The study is for an eight-month period; work planned for the next three months is outlined.

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GLOSSARY

A&O R/M	Atmospheric and Oceanographic Imaging Radar Experiment
AMBA	Adaptive Multi-Beam Antennas Experiment
ARE	Antenna Range Experiment
ATTN	RF Attenuator
BPF	Bandpass Filter
BPF/DIP	Band Pass Filter and Diplexer Combination
BPF/MUX	Band Pass Filter and Multiplexer Combination
bps	Bits per Second
BW	Bandwidth, Refers to Frequency
CCT	Computer Compatible Tape
CHA	Corrugated Horn Antenna
CMD	Command
CONUS	Continental United States
CRT	Cathode Ray Tube
CSSR	Cooperative Surveillance
CTRL	Control
DBMGT	Data Base Management, A Centralized Systems for Control of Stored Data
DCMB	Data Collection With Multi-Beam Experiment
DEL	Smallest Unit Size of Data
DEMOD	Signal Demodulator

DEMUX	Demultiplexer
DIP	Frequency Diplexer
DN/CNVR	Down Converter
DP	Data Processing
EE	Electromagnetic (interference) Environment
EEE	Electromagnetic Environment Experiment
EIRP	Effective Isotropic Radiated Power
F	Frequency
FCC	Federal Communications Commission
Field	A Single Piece of Data Such as a Number or Word
Forward Link	Data Link from OCC to Deployed Satellite or Sensor System
GPS	NAVSTAR/GPS Experiment
H	Orbit Height
HDDT	High Density Digital Tape
HPBW	Half Power Beam Width
ID	Identification
I/F	Attitude/Position Location Interferometer
I/O	Input to and/or Output from a Computer
IP	Input
IRAC	Interdepartment Radio Advisory Committee (U.S. Government)
ITU	International Telecommunications Union
K	Kilo-one Thousand
Kbps	Kilo-bits per Second
KM	Kilometers

LHCP	Left Hand Circular Polarization
LNA	Low Noise Amplifier
LNA/DIP	Low Noise Amplifier and Diplexer Combination
LO	Local Oscillator Signal
LOCN	Location
LOGP	Log Periodic RF Feed
M	Mega - One Million
Mbps	Mega-bits per Second
METRAD	Meteorological Radar
MMAP	Microwave Multi-Application Payload
MMWC	Millimeter Wave Communications Experiment
MUX	Multiplexer
MWISE	Microwave Imaging Spectrometer Experiment
n	Decimal Integer
OCC	Operations Control Center, A Ground Facility for Mission Control
OP	Output
OS	Operating System, A Computer Program for Controlling the Operation of all the other Programs in the Computer
POLC	Polarization Control
RCVR	Receiver
Record	An Entry in a Data File
Reverse Link	Data Link from a Deployed Satellite or Sensor to OCC
RF	Radio Frequency

RFI	Radio Frequency Interference
RHCP	Right Hand Circular Polarization
SMS R/M	Soil Moisture and Salinity Radiometer Experiment
SSR	Surface Spectrum Radar Experiment
STAT(S)	Statistic(s)
STDN	Spaceflight Tracking and Data Network
T&C	Telemetry and Control
TBD	To Be Determined
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TLM	Telemetry
TT&C	Telemetry, Tracking and Control
U	Unit Frequency Resolution Bandwidth
UAA	Upper Antenna Assembly
WARC	World Administrative Radio Conference (ITU)
WBR	Wide Band Receiver
XMT	Transmitter

SECTION 1
INTRODUCTION

The National Aeronautics and Space Administration (NASA) has proposed a Shuttle/ Spacelab Electromagnetic Environmental Experiment (EEE) to measure and characterize earth-emitted, electromagnetic (interference) environment at frequencies allocated for space use, or potential space use, over the frequency range of 0.4 to 40 GHz. Since radio frequency (RF) spectrum occupancy is experiencing an exponential growth, an object of this experiment is to establish a capability for continuous RF spectrum monitoring and electromagnetic environment (EE) mapping from space. The Shuttle/ Spacelab provides an opportunity to develop space-monitoring EE capability that will prove valuable both to NASA as a spectrum user, and to governmental regulatory agencies including the Federal Communications (FCC) and United Nations agencies such as the International Telecommunications Union (ITU), the U.S. Government Interdepartment Radio Advisory Committee (IRAC) and the World Administrative Radio Conference (WARC) of the ITU.

The Shuttle/Spacelab offers a unique opportunity to measure the electromagnetic environment over a short time interval, 7-30 days, analyze data rapidly, and optimize control of the experiment or data processing through the use of an on-board specialist and on-board data display equipment. Repetitive Shuttle flights also provide additional flexibility in extended experiments and mission control. Furthermore, the Shuttle provides the means for launching and retrieving "Free-Flyer" near-earth satellites for continuous monitoring earth electromagnetic environment over longer periods.

Data transfer from the Shuttle/Spacelab will be through the Tracking and Data Relay Satellite System (TDRSS), through the Spaceflight Tracking and Data Network (STDN), and retrieval of data storage tapes at the end of a flight. Data transfer will be real-time, delayed data dump from an on-board recorder, and tape retrieval. Final analysis of data will be done at a NASA-based processing center which will provide user information in various categories.

In September 1974 the University of Pennsylvania was awarded a Phase A Definition Study contract to plan a preliminary Electromagnetic Environment Experiment (EEE), to conduct a Shuttle/Spacelab antenna analysis for EEE and to devise an RF Propagation Model for the experiment. In June 1975, four contracts were awarded for the Phase B Definition Study. These were:

1. EE Experiment Definition Study - General Electric Company, Valley Forge Space Division, Philadelphia, Pa.
2. EE Experiment Antenna Design - Hughes Aircraft Company, Culver City, Calif.
3. EE Experiment Electronics Package Design - Culter-Hammer, AIL, Deer Part, N.Y.
4. EE Experiment Data Processing/Display Design - Techno Sciences Inc., Costa Mesa, Calif.

This report covers the work completed during the first five months on the Experiment Definition Study.

1.1 EXPERIMENT OBJECTIVES

The primary objective of the EEE is to measure and characterize electromagnetic environment interference at frequencies allocated for space use by establishing a capability for monitoring the RF spectrum in the frequency range of 0.4 to 40 GHz. An objective of the Shuttle/Spacelab experiment is to determine feasibility of monitoring earth-based interference from space and to establish techniques for measurement, storage and processing of data.

Design of the EEE involves many technologies which have undergone rapid advances in recent years. These new technologies, coupled with recent studies of atmospheric propagation and Shuttle mission capabilities, provide a new base from which to design the EE. Therefore, the objectives of the Definition Study are to determine the feasibility of the experiment based on existing technology, prepare operational procedures for the equipment, establish design and reliability criteria for Shuttle equipment, determine

mission profiles for the Shuttle, and outline techniques for processing and displaying data obtained from the Experiment. Outputs from the study will include an experiment design, operation and mission profiles, a data handling system and plans for future experiments such as free-flyer, Shuttle-launch satellites to continuously monitor interference environment for specific frequency bands.

1.2 STUDY APPROACH

The EEE will be developed along with twelve or so other experiments which will be integrated into a single Shuttle payload. This payload is designated the Microwave Multi-Application Payload (MMAP). Certain experiments interface directly with EEE and use common equipment, primarily antennas. These experiments are listed in Appendix A and will be referred to throughout this report to define interfaces.

The approach to this Definition Study is to analyze and define the EEE as an integral part of the MMAP Payload. Where practical, equipment will be shared and sized to allow the entire payload to be contained on the Shuttle. Examples of common equipment are antennas, power supplies, data processing and storage, and antenna deployment mechanisms. Full consideration of the total MMAP Payload is needed for mission planning, equipment sizing and mounting, data handling, payload EMI, on-board payload personnel requirements, and other Shuttle related parameters such as weight, power requirements and on-board displays. The net effect of the MMAP/EEE approach is that all the MMAP experiments become an integral part of the EEE Definition Study. Throughout this report interfaces with other experiments are shown prominently, and where applicable, interface parameters are included.

SECTION 2
EXPERIMENT DEFINITION

2.1 MISSION PLANNING STUDIES

Mission planning studies for the EEE were performed to establish operating times for the experiment and to obtain the maximum geographical coverage possible on a typical 7-day Shuttle mission during the 1981-82 time frame. During this time period the Shuttle will be launched from the Eastern Test Range (ETR), Cape Canaveral, Florida, and the maximum orbit inclination being 57^{o} (Reference 1).

The EEE mission is to map electromagnetic radiation from the earth, and its orbit profile should cover those areas which are most likely to have interference emissions. Figure 2-1 shows six geographical regions which cover most of the possible sources of electromagnetic emissions known today. The CONUS region, contained in North America, is of special interest and will be treated in detail in the following analyses.

To obtain reasonable operation parameters, certain mission guidelines were established. For example, a 7-day orbiter mission is in reality a 6-day mission for EEE, since 1/2 day is needed for orbiter check-out, equipment deployment and experiment check-out, and 1/2 day is needed for orbiter landing preparation. A circular orbit is assumed and orbit altitude is assumed 400 km. Knowing that the launch will be from the ETR, the basic mission parameters for the study can be established as follows:

1. Mission Duration: 6 days
2. Orbit Inclination: 57^{o}
3. Altitude: 400 km
4. Orbit Shape: Circular
5. Insertion Point: ETR (28.5^{o}N, 80.5^{o}W)

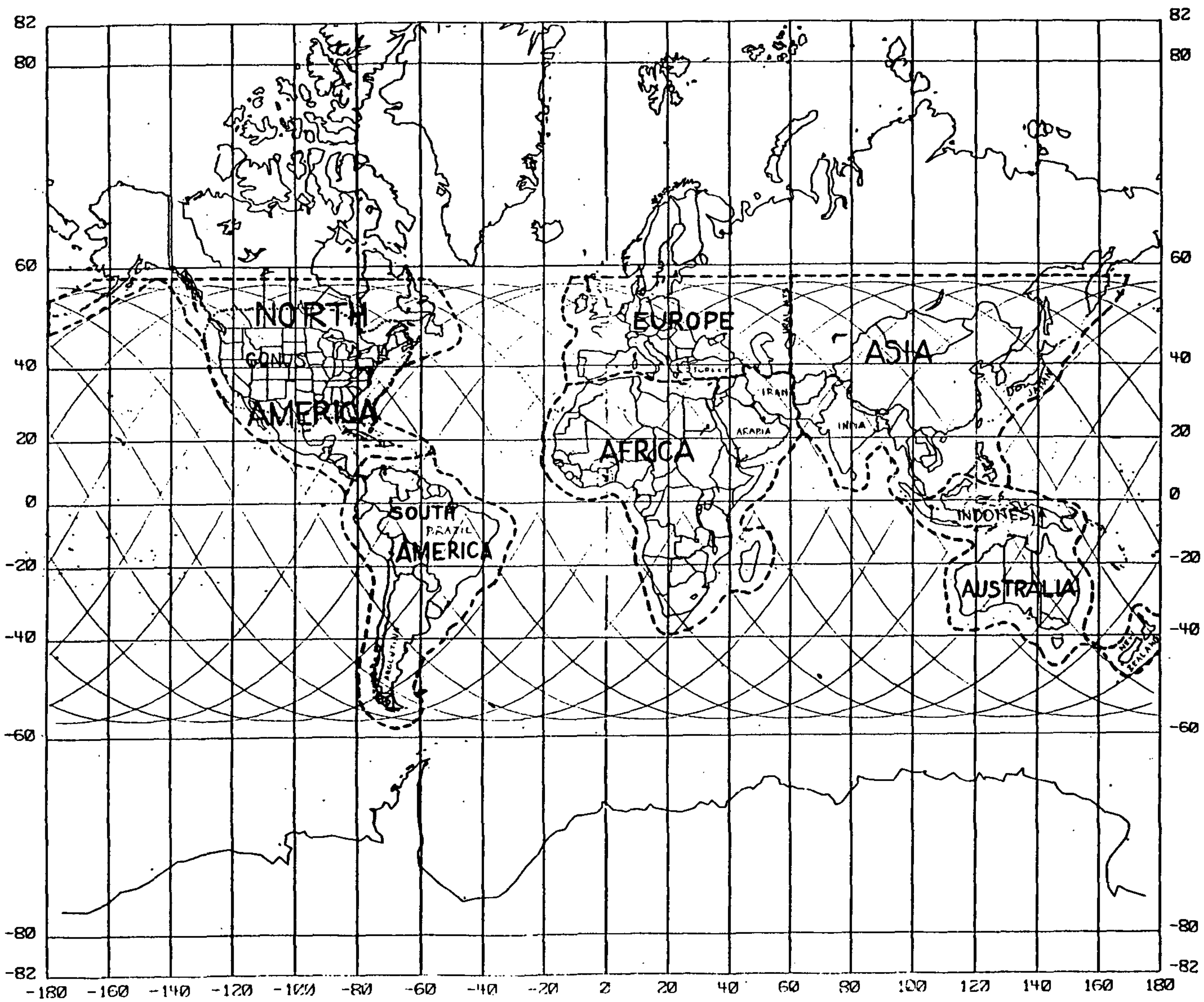


Figure 2-1. Typical EEE Region of Interest/First Day Orbit Traces

The above parameters define a mission profile that covers an area symmetrical about the equator and bounded by $\pm 57^{\circ}$ latitude. Figure 2-1 shows the typical first-day traces of an orbiter inserted in orbit at the ETR and exhibiting these parameters. Characteristics of the profile are:

1. Exact 3 day repeat orbit
2. Orbit period 92.65 minutes (15.54 revolutions/day)
3. Orbits per 6 day missions: 93.34
4. Distance between adjacent orbits 7.7° = 491.87 nm = 910.94 km (ref. Equator)
5. Orbits over CONUS: 21 per 3 day cycle = 42

Figure 2-1 shows a representative orbit pattern for the first day of a mission. During the second and third days the orbit traces move progressively eastward to fill the area between the traces shown, providing two additional traces between each trace shown in Figure 2-1. The resulting grid over the CONUS is shown in Figure 2-2. This grid and similar grids over the other regions of interest was used to determine fly-over times and EEE operating periods.

Table 2-1 shows typical viewing time for each of the regions outlined in Figure 2-1. Note that the total viewing time for all six geographical regions is 58.93 hours for the entire 6-day mission. Extending this analysis to the CONUS only (Table 2-2), the viewing time is about 50 minutes per day and only 5.15 hours total. Some fly-over times are extremely short, e.g., Nos. 5 and 35 orbits, and no fly-over occurs for orbit Nos. 20 and 66.

The distribution of the CONUS observations times can be seen in Figures 2-3. Shown are the times of orbit coverages for the six days (from Table 2-2 data) plotted on a 24-hour basis starting with the indicated T_0 time reference. Note that all operating times are in nearly the same block of hours each day. Thus, a six-day mission would not provide for viewing during both daylight and night hours. To cover both day and night on the same mission, a longer mission period is required or orbit parameters must be altered, e.g., change of altitude, orbit inclination and launch site.

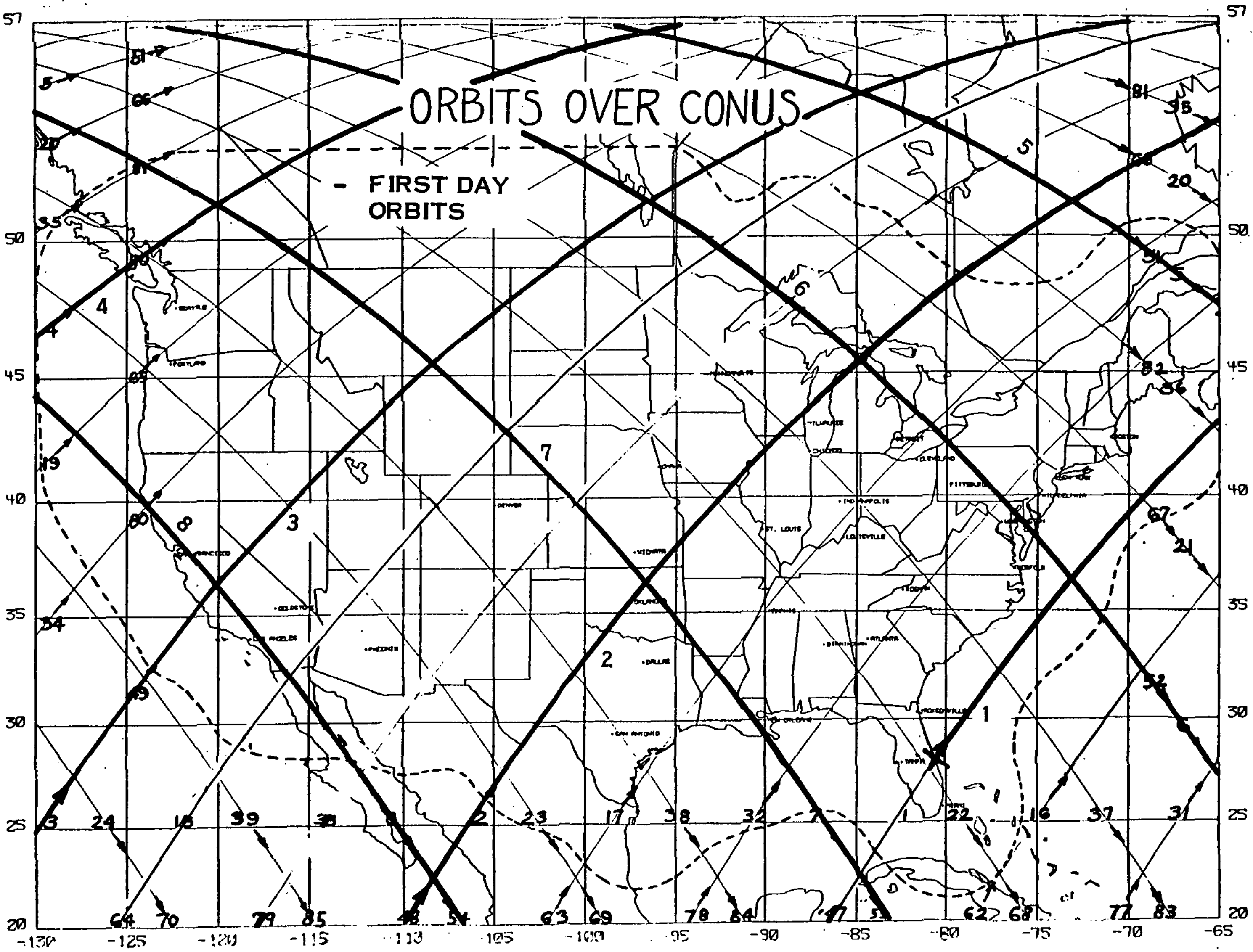


Figure 2-2. CONUS Orbit Pattern (6-Day Mission)

Table 2-1. Estimated Viewing Times* for Global Areas

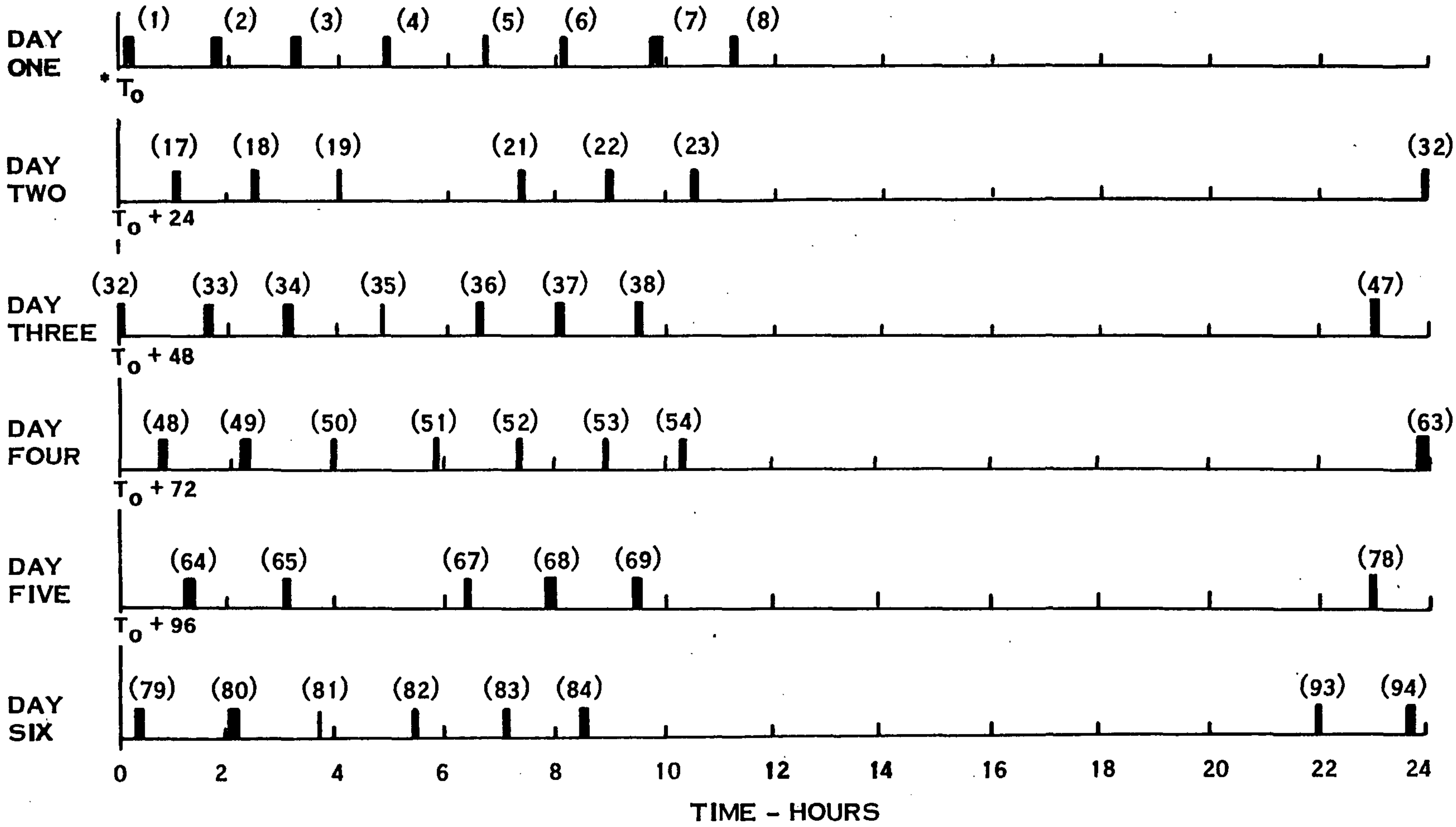
Areas	Time - 6 Day Mission
CONUS - also included in North America time	5.15 Hours
North America - Includes, Canada, Central America, and Caribbean area as well as CONUS	11.87
South America - As shown	7.12
Europe - West of Ural Mountains; includes Turkey	7.21
Africa - Includes Arabia and Iran	11.00
Asia - East of Ural Mountains	15.44
Australia - Includes New Zealand and Indonesia	6.29
Six-Day Total	58.93 Hours

*Includes one minute operation at each end of each orbit outside applicable boundary or shoreline (See Figure 2-1)

Table 2-2. Operating Time Over CONUS* (Minutes)

Day 1		Day 2		Day 3		Day 4		Day 5		Day 6	
Orbit	Time	Orbit	Time	Orbit	Time	Orbit	Time	Orbit	Time	Orbit	Time
1	7.5	17	9.75	32	4.98	48	8.4	64	8.82	79	8.15
2	8.4	18	8.82	33	8.15	49	7.7	65	4.75	80	6.65
3	7.7	19	4.75	34	6.65	50	2.65	66	x	81	.50
4	2.65	20	x	35	.50	51	1.85	67	6.35	82	3.05
5	1.85	21	6.35	36	3.05	52	7.75	68	11.35	83	8.5
6	7.75	22	11.35	37	8.5	53	9.75	69	8.4	84	9.8
7	9.75	23	8.4	38	9.8	54	5.3				
8	5.3										
										93	7.5
		32	3.0	47	7.5	63	9.75	78	7.98	94	8.4
Total	50.90		52.42		49.13		53.15		50.65		52.55
Six Day Total:	308.80 Minutes										
	5.15 Hours										

*Assumes one additional minute of operation at each end of orbit path over the U.S. beyond the border/coastline crossings (See Figure 2-2)



*T_o REFERENCE IS ORBIT NO. 1 CROSSING OF EQUATOR, ASCENDING ORBIT, 57° INCLINATION

( ) = ORBIT NUMBER

Figure 2-3. Operating Times Over CONUS for Six Day Mission

2.2 ANTENNA SCANNING STUDIES

Summary

The antenna coverage areas on the surface of the earth, as seen by the radiation beams of the MMAP/EEE antennas, are analyzed in this section. The impact of the path length variations on the radiation beams and the footprints is taken into consideration. The following six scanning techniques are discussed in succeeding sections along with their applicability to the MMAP/EEE mission requirements.

1. Circular Control Scanning of the Horizon

   Circular conical scanning[3] of the horizon with concentric radiation beams, directed with their common axis 0.5° below the horizon line proved to yield optimum footprints for horizon coverage. The scanned areas, per revolution, are more than 40 percent of the earth cap below the shuttle at the highest frequency and more than 80 percent at the lowest frequency. This technique provides a large detection probability for most of the radiating sources with low angle beams (see Figure 2-4) but has the disadvantage of decreased sensitivity and larger antenna footprints.

2. Spiral Conical Scanning

   The conical spiral scanning mode provides coverage for high angle emitters near nadir. However, a fast scanning speed is required when the elevation angle is less than about 50°. At present, maximum scanning speed of 60°/sec is proposed for the antenna assembly. This speed yields only partial coverage near nadir and results in only a modest probability of detection.

3. Radial Conical Scanning

   The radial scanning mode offers coverage near nadir, but has the same scanning speed limitations as the conical spiral scanning mode. It has the advantages, however, of thoroughly investigating specific areas to the left and right of the Space Shuttle and near nadir.

4. Dual Beamwidth Scanning

   To overcome some of the disadvantages of the previous three techniques, combinations of narrow and broadbeam antennas are proposed to provide complete coverage when using the conical spiral scanning mode. The scheme proposed is to use the narrowbeam antennas when the elevation angle is large, near the horizon, and as the elevation angle decreases, the broadbeam antenna would provide coverage for angles less than about 45°. Some loss of sensitivity is expected, but greater coverage is expected.

5. Sector Scanning

   The Sector Scan[7] mode is proposed for scanning with the beam axis several degrees below the horizon and is primarily useful for detection of specific

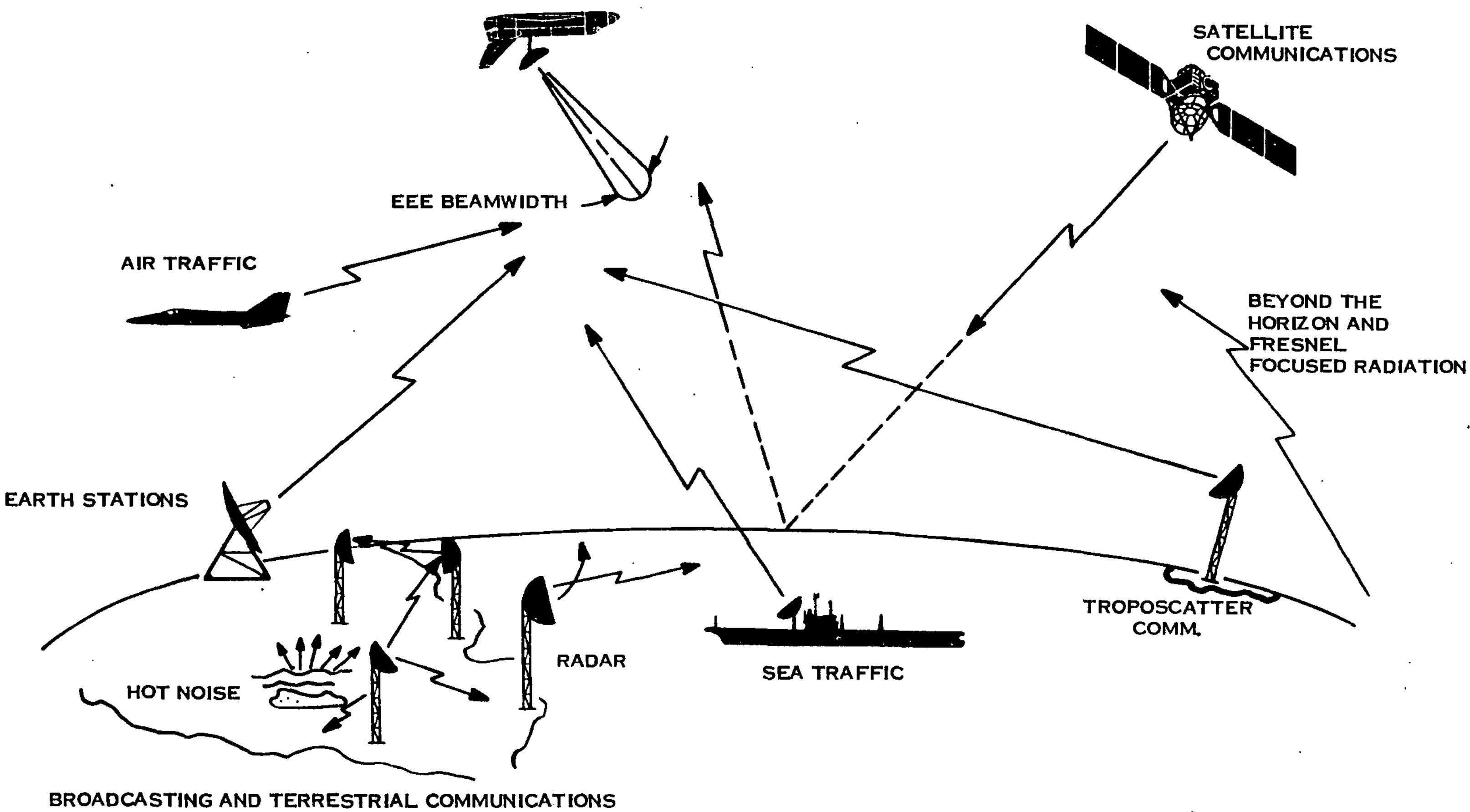


Figure 2-4. Typical Microwave Radiation Sources

radiators, e.g., horizon pointing radars. Scanning speeds are reasonably slow, 5-10° per second, and a wide geographical area can be covered with a reasonable scan angles e.g., $\pm 10^{\circ}$ to $\pm 20^{\circ}$. Correction for Doppler frequency shift must be provided as a function of the azimuth scan angle, i.e., for looking directly forward and aft the Doppler correction is maximum, and for scanning off the side almost no correction is needed.

6. Manual Operation

   For scanning of specific emitters, a manual scanning mode could be used. This would provide the capability to switch to any of the previous auto-scan modes for particular time intervals and in addition provide for coverage of specific zones by allowing the Mission Specialist to program his own scanning mode. This mode provides flexibility which the Mission Specialist could use for special investigations.

2.2.1 INTRODUCTION

The EEE mission is mainly concerned with the identification of RFI sources. This identification is determined by the capability of the EEE radiated beams to fully scan the probable geographic locations, the directions and frequencies of the radiation sources. The main measurable parameters are EIRP levels, frequencies, locations of the sources, and to some extent elevation angle of the radiating sources. The location of the sources is mainly determined by the orbit configuration, the scanning techniques of the onboard antennas, the main beam shapes and side-lobe levels, and to some extent the dynamic range of the MMAP/EEE receivers. A large dynamic receiver range and low antenna side-lobe levels are required to be able to discriminate between powerful radiation sources off the main beam and sources within the main beam. In addition, microwave radiation sources on earth are generally more directive, smaller in number and more discrete at high frequencies than at low frequencies. Consequently, the probability of detecting and identifying emitters in the bands above 18 GHz is low. Many emitters will be from moving bases and will probably result in a number of unaccountable emitters. A summary of typical emitters is given in Figure 2-4. These fall into the following categories:

1. Radar installations
2. Terrestrial line of sight relays (4-6-10-12...GHz)
3. Earth station terminals

4. Aircraft traffic systems (mainly L-band)

5. Sea traffic installations and ships

6. Satellites orbiting the earth and radiating in direct path to the EEE antennas or through reflection from sea and ground

7. Troposcatter high power terminals

In order to identify these sources with their complex location patterns and envelopes of interfering radiations, involved techniques are needed for scanning and data processing. This section mainly describes the antenna scanning techniques and defines radiation beam requirements for the EEE missions. (Data processing is covered in Section 2.3.)

2.2.2 FORMULATION OF THE PROBLEM

From the point of view of the spectrum utilization and the evaluation of the EIRP levels for most radiating sources it is sufficient to use circular conical scanning of the horizon. This mode yields the largest area coverage of the antenna footprints (as later explained) and hence needs low scanning rates which increase the dwell times needed to fully identify the radiating sources. Among the advantages of this simple scanning mode are the increase of probability of detection of line of sight network radiators, reduction of the problems of direct ground or sea reflections of high elevated terminals and the reduction of troposcatter effects of small turn angles.

When a radiation beam is directed from the shuttle to the surface of the earth with its edge at the horizon line (as illustrated in Figure 2-5) the maximum arc extent of the footprint X is related to the beamwidth α as follows:

$$X = R\,\theta_2 = R\left\{\cos^{-1}\left[\left(\frac{R+H}{R}\right)\sin\nu\right] - \alpha\right\},$$

where

$$\nu = \left[\sin^{-1}\left(\frac{R}{R+H}\right) - \alpha\right]$$

is the angle between nadir and the lowest HPBW edge of the beam.

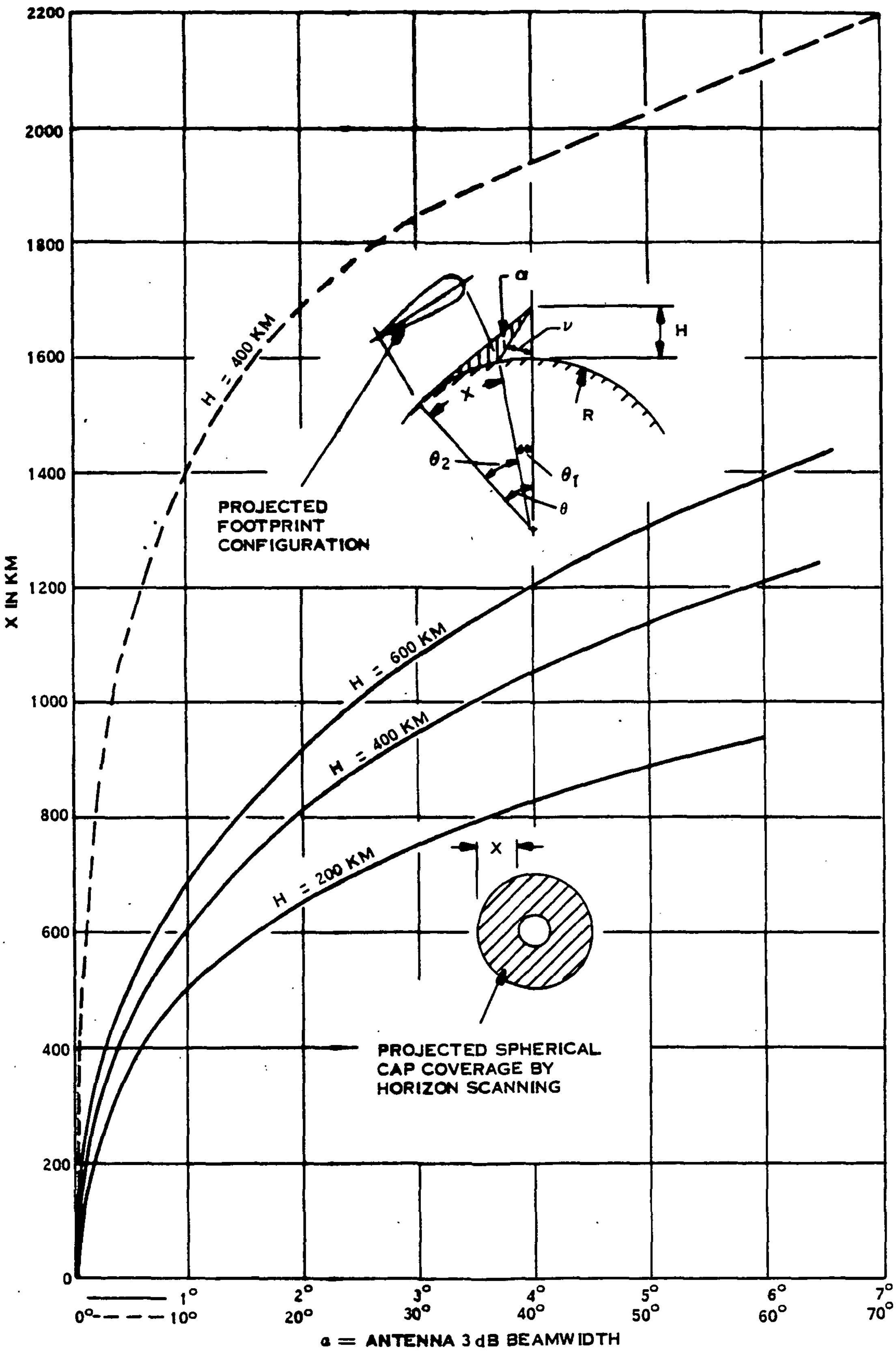


Figure 2-5. Maximum Extent of the Footprint (X) with HPBW Beam Edge on the Horizon

This relation is plotted in Figure 2-5. It is easy to see in this figure that the rate of increase of the coverage parameter X, with narrow beamwidths, is much larger than its rate at broad beamwidths. This indicates that the horizon coverage may effectively be achieved at different frequencies when the beam edges are adjusted to point to the horizon line.

When circular scanning is performed using these edge horizon directed beams the scanned area A_s (which is generated by rotation of the spherical arc X around a vertical axis passing through the shuttle) is given by

$$A_s = 2 \pi R^2 \left[(1 - \cos \theta) - (1 - \cos \theta_1)\right]$$

The total area of the spherical cap (from horizon to horizon) below the shuttle is given by

$$A = 2 \pi R^2 (1 - \cos \theta).$$

This means that the percentage of the circularly scanned area using a beam width α, with the beam edge directed to the horizon, is given by

$$\frac{A_s}{A} = \left[1 - \frac{(1 - \cos \theta_1)}{(1 - \cos \theta)}\right]$$

Figure 2-6 shows the relation between this ratio (in percentage) and the antenna beamwidth. For a 1° beam the area covered by circular scanning is more than 45 percent of the area of the horizon spherical cap, where asfor an 8° beamwidth this percentage is more than 80 percent. This shows the extremely good coverage and high probability of detection of sources having low angle elevated beams when using horizon circular scanning. Factors which need to be considered in order to utilize this advantage are:

1. Eccentricity of Radiation Beams

   An antenna design needs to be considered which yields radiation beams having common beam edges directed to the horizon, as shown in Figure 2-7. Such an antenna may be designed by making use of log periodic feeds having their axis at a specific tilt angle relative to the axis of the reflector. This requirement, however, is shown later to be unnecessary because the spherical surface of the earth yields natural shift of the beam axis of radiation which leads to natural eccentricity of the radiation beams.

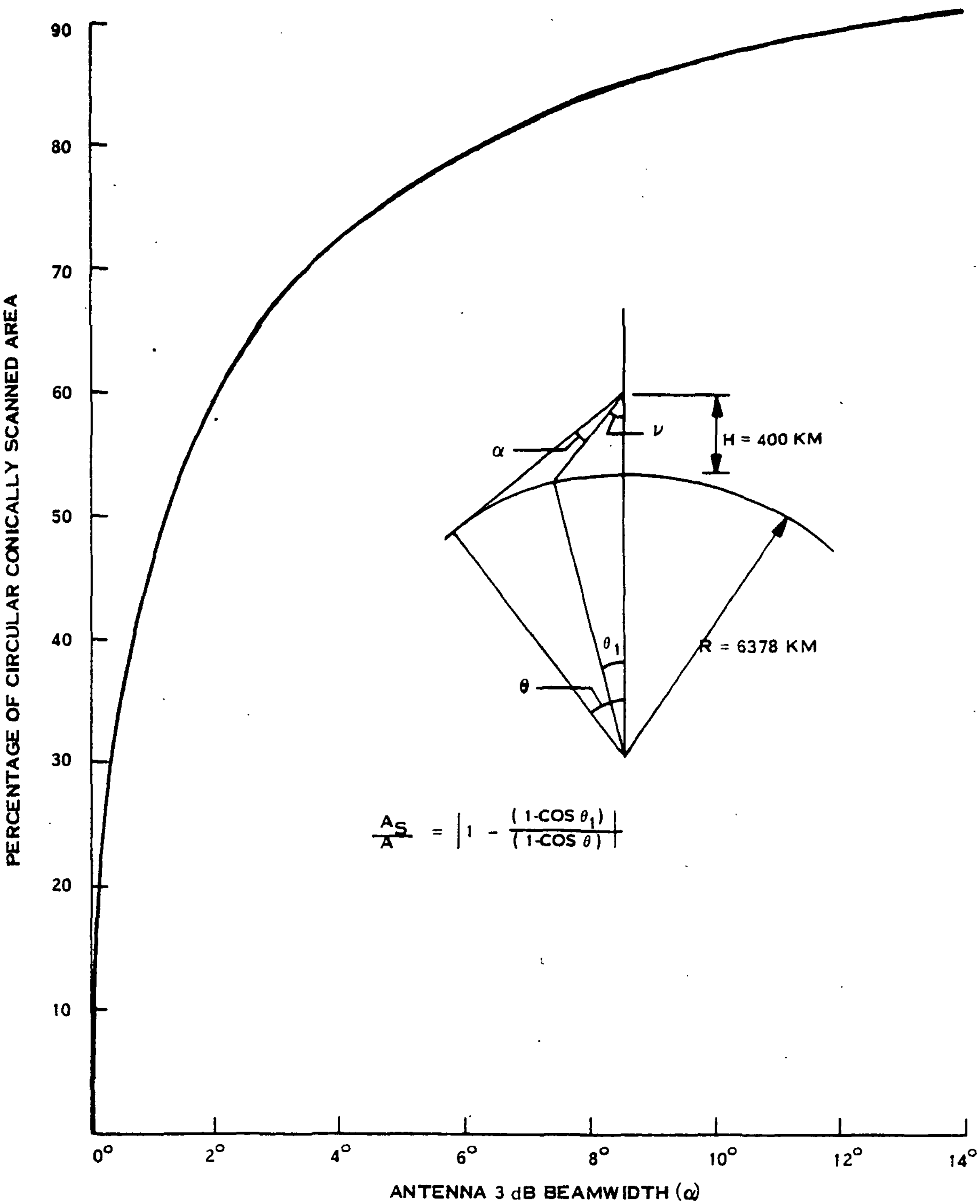


Figure 2-6. Scanned Area Below the Shuttle Using Horizon Circular Scanning with Beam Edge at the Horizon

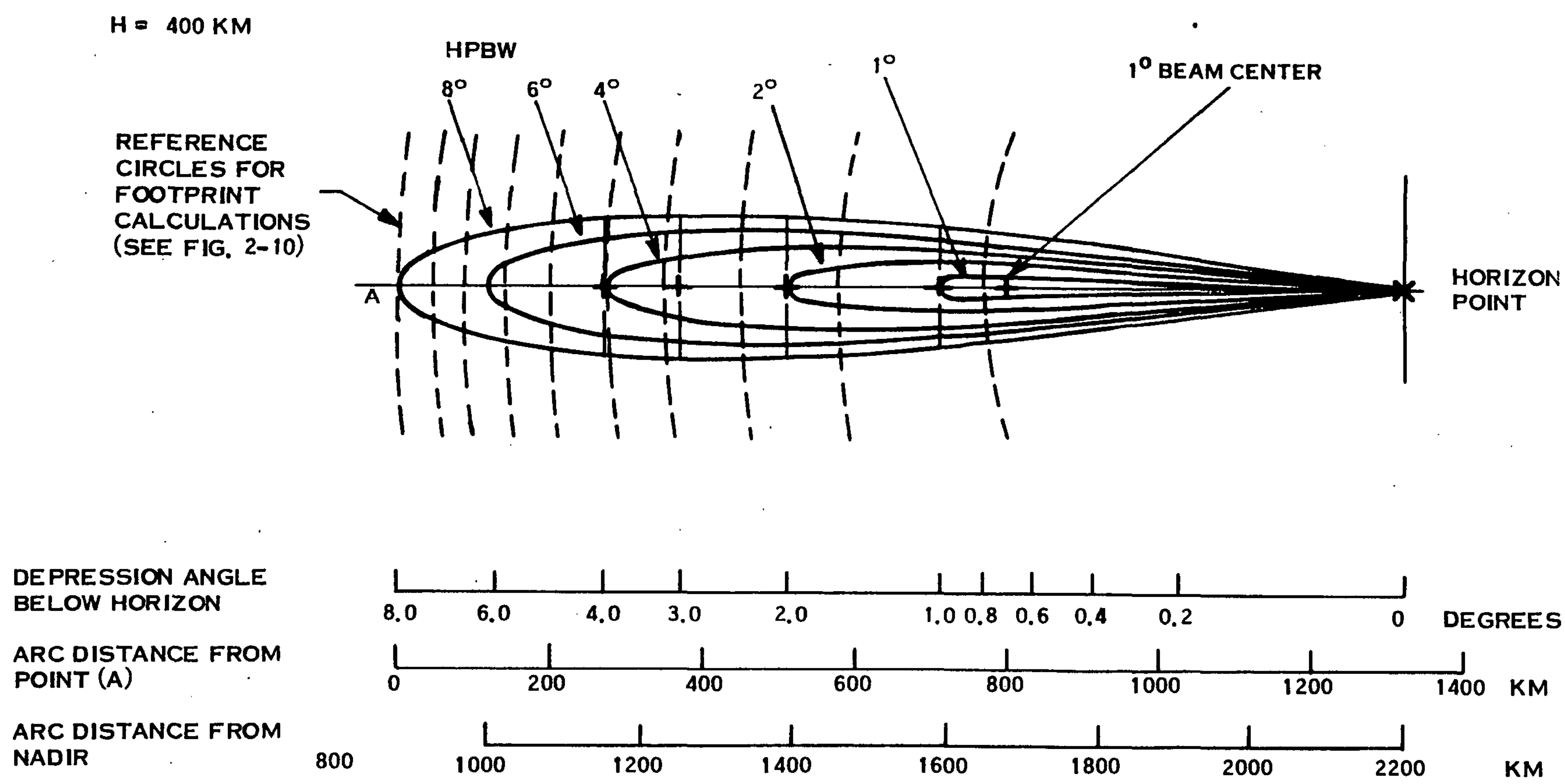


Figure 2-7. Footprints of the Antenna Beams with Edges at Horizon (3mDish)

2. Scanning Speed

The speed of rotation for the circular conical scanning is to be adjusted so that the forward speed of the space shuttle with yield proper overlap of successive rings of the helical pattern of the antenna footprint at the highest frequency. At low frequencies (i.e., with broader beamwidths) larger overlap of the successive rings of the helical path results in larger overlap of the footprints and hence larger detection probability of the radiation sources.

3. Elevation Angle of Earth Based Emitters

The range of elevation angles of the detectable radiating sources (through their main beams), on earth, when using the circular horizon scanning, changes from zero at the horizon to 6° at the nearest edge of the 1° beam, whereas the range of elevation angles is between zero and 26° for the 8° beamwidth. Figure 2-8 shows the change of the elevation angles of terrestrial sources, when received through these main beams of radiation, as function of the look angle of the EEE antennas (off nadir). The large change of elevation angles of the detectable terrestrial beams within the footprints of the MMAP/EEE beams of radiation (especially near the horizon) indicates expected distoriton of the measured EIRP levels (especially for high directive radiators) and emphasizes the requirement of large overlap for the successive rings of the helical pattern of the narrowest beamwidth in order to increase the detection probability of the radiation sources.

4. Horizon Coverage

In order to increase the dwell time on sources at the horizon, it is necessary to slightly elevate the beams of radiation so that good horizon coverage may be achieved.

5. Path Length Variation Effects

Adjustments of the orientation angle and the eccentricity of the MMAP/EEE antennas near the horizon, in order to achieve optimum horizon scanning, is mainly controlled by the path length variations from the nearest to the outermost edges of the beam. This results in the shift of the beam centers in the direction of nadir and to an effective change of the beamwidth. An example of this distortion for a 30° beam is shown in Figure 2-9. An illustration of this situation is also shown in Figure 2-14. This means that for proper overlap of the beams at the horizon the eccentricity of each beam may be adjusted by increasing the elevation of the beam so that its effective 3 dB point is slightly above the horizon line. This amount of beam shift is not a linear relation with the beamwidth.

In order to achieve good horizon coverage it is required to find the combination of beams which yield an overlap configuration of footprints similar to the configuration of Figure 2-7. (The beams of Figure 2-7 are used because of their representation to the range of beamwidths of the 3m dish.) It is easy to recognize from the configuration of the

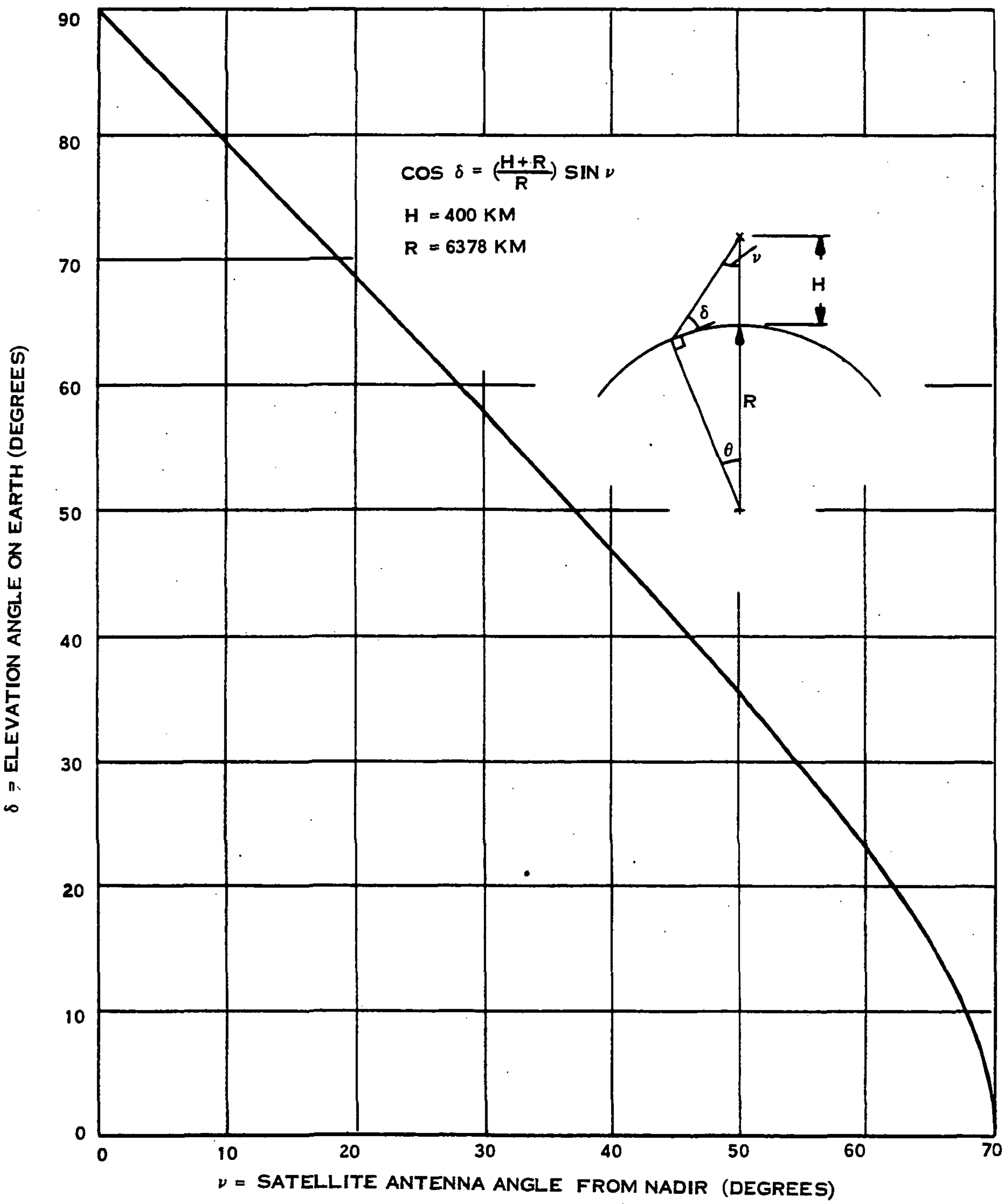


Figure 2-8. Elevation Angle of Terrestrial Antennas

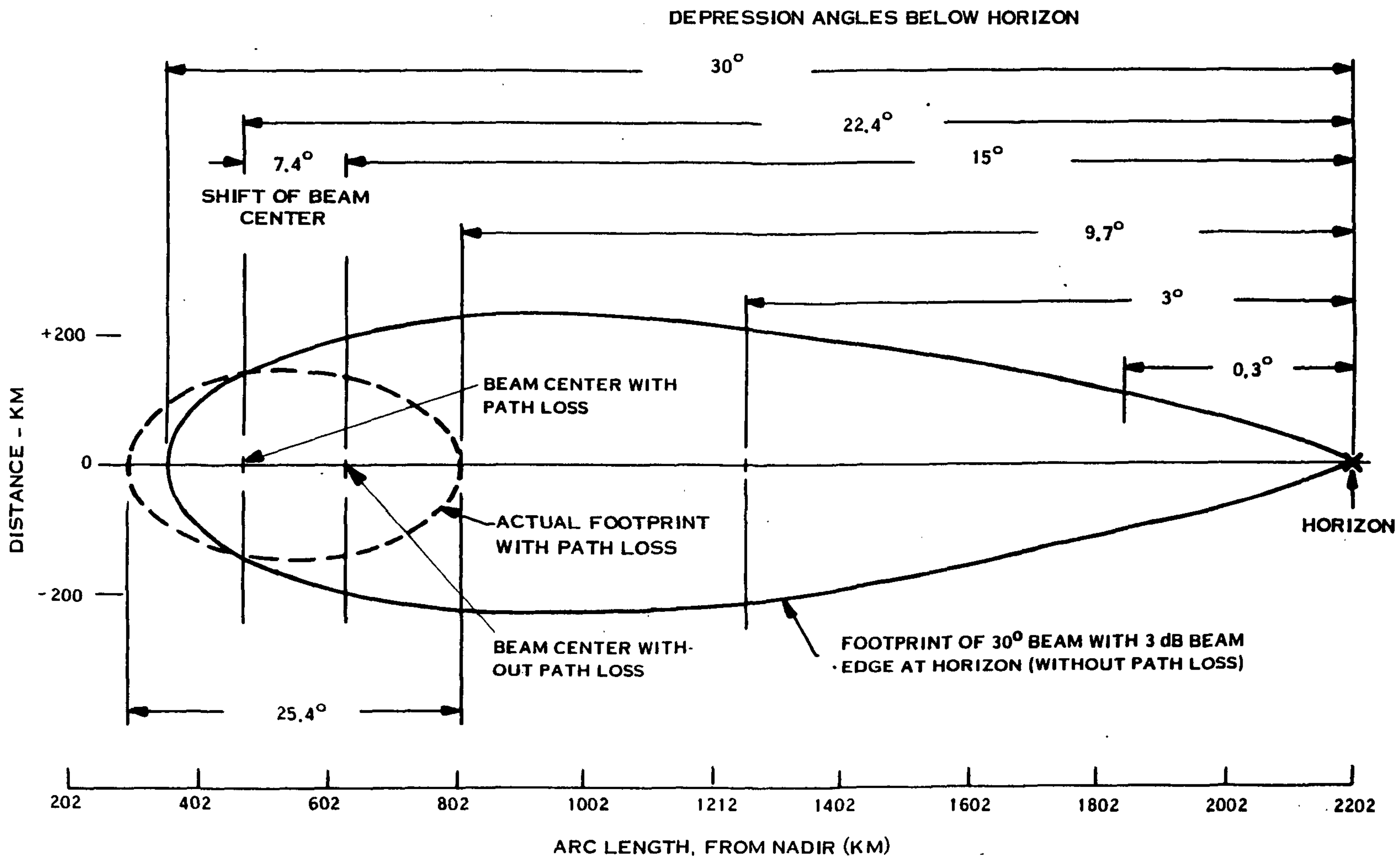


Figure 2-9. Footprints of a 30° Beam

system that wide beams suffer more distoriton due to path length variations than the distortion of narrow beams. Consequently the footprints of concentric beams of the 3m dish are expected to have dispersion of their axes similar to the dispersion of the beam axes of Figure 2-7. The question, however, is if the dispersion can be adjusted to match the dispersion of Figure 2-7. The easiest adjustment procedure is to find the footprint configurations at varieties of elevation angles of the beams. The footprint configuration of Figure 2-21 is found to have overlap configurations similar to the footprints of Figure 2-7. The one degree and the 15^{0} beams, however, of Figure 2-21 stop short of the horizon point, which indicates the requirement to increase the elevation of the beams of Figure 2-21 to match those of Figure 2-7. The determining factor is compromise between good coverage at the overlap area of all the beams (at the horizon), large interference due to beyond the horizon propagation effects and complete coverage due to propagation effects near the horizon (as explained in Section 2.2.5).

When circular scanning is performed for regions below the horizon, near to nadir, the footprint configurations change and tend to be concentric. This means that the overlap of the circular scanning needs to be adjusted to obtain full coverage at the highest frequency and to allow beam overlap at lower frequencies. The easiest solutions for analyzing requirements for varying pointing angles is to use antennas with constant radiating beamwidth for all frequencies. This is a design hardship for the antennas, leads to less efficient antennas and reduced system sensitivity (see Reference 2). The most practical approach is to use conventional concentric beams (aligned along the same axis of the antenna) and to introduce a software pointing correction factor which is a function of the beam off nadir. These considerations are discussed in detail in the following section.

2.2.3 ACTUAL FOOTPRINTS OF ANTENNA BEAMS AND THE EFFECTIVE ANGLE AND BEAMWIDTH OF THESE BEAMS

The path length attenuation factor distorts the beam shape, causing ellipicity for pencil beams and shift of their effective axis of radiation in the direction of nadir. Using the configuration and equations of Figures 2-10 and 2-11, the path length and attenuation factors (at different frequencies) vary as shown in Figures 2-12 and 2-13, respectively.

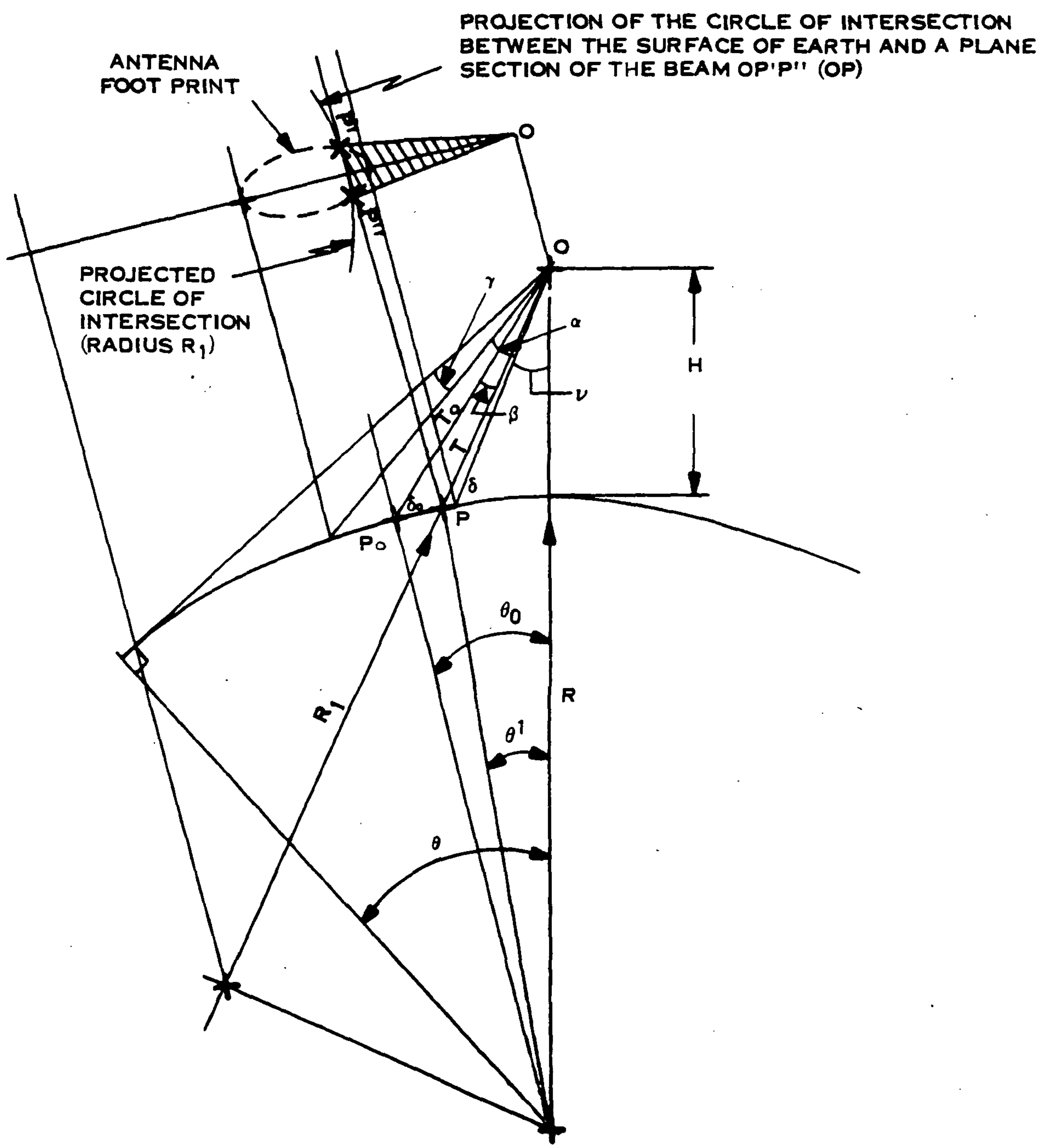
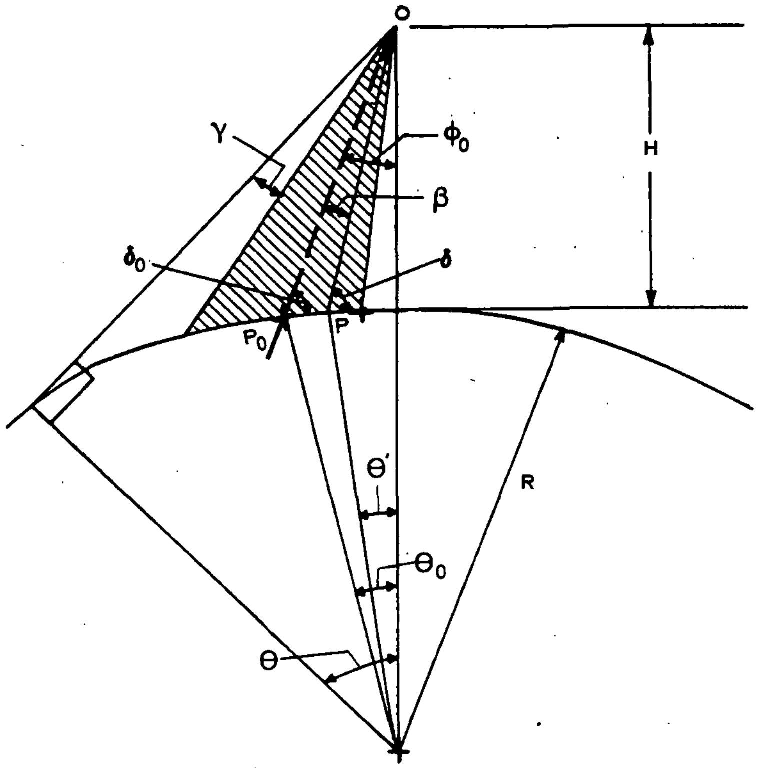


Figure 2-10. Geometry of the Footprint Calculating Parameters



H = 400 KM
R = 6378 KM

x = INCREMENT OF BEAM WIDTH

γ = DEPRESSION ANGLE OF BEAM EDGE BELOW HORIZON LINE

$$\theta = \cos^{-1}\left(\frac{R}{R+H}\right)$$

$$\theta' = (\pi/2) - \delta_o - \phi_o$$

$$\delta = \cos^{-1}\left[\left(\frac{R+H}{R}\right)\,\mathrm{SIN}\,(\phi_o - \beta)\right]$$

$$\theta = (\pi/2) - \delta - (\phi_o - \beta)$$

$$T_o = OP_o = R\left(\frac{\mathrm{SIN}\,\theta_o}{\mathrm{SIN}\,\phi_o}\right)$$

$$T = OP = R\left[\frac{\mathrm{SIN}\,\theta'}{\mathrm{SIN}\,(\phi_o - \beta)}\right]$$

E_o = $[\mathrm{SIN}\,(2.7834\,x)]\,/(2.7834\,x)$ = THE NORMALIZED RADIATION PATTERN

E = $E_o\,(T_o/T)$ = THE RADIATION PATTERN, TAKING THE PATH LENGTH INTO CONSIDERATION

Figure 2-11. Satellite to Earth Path Length Parameters

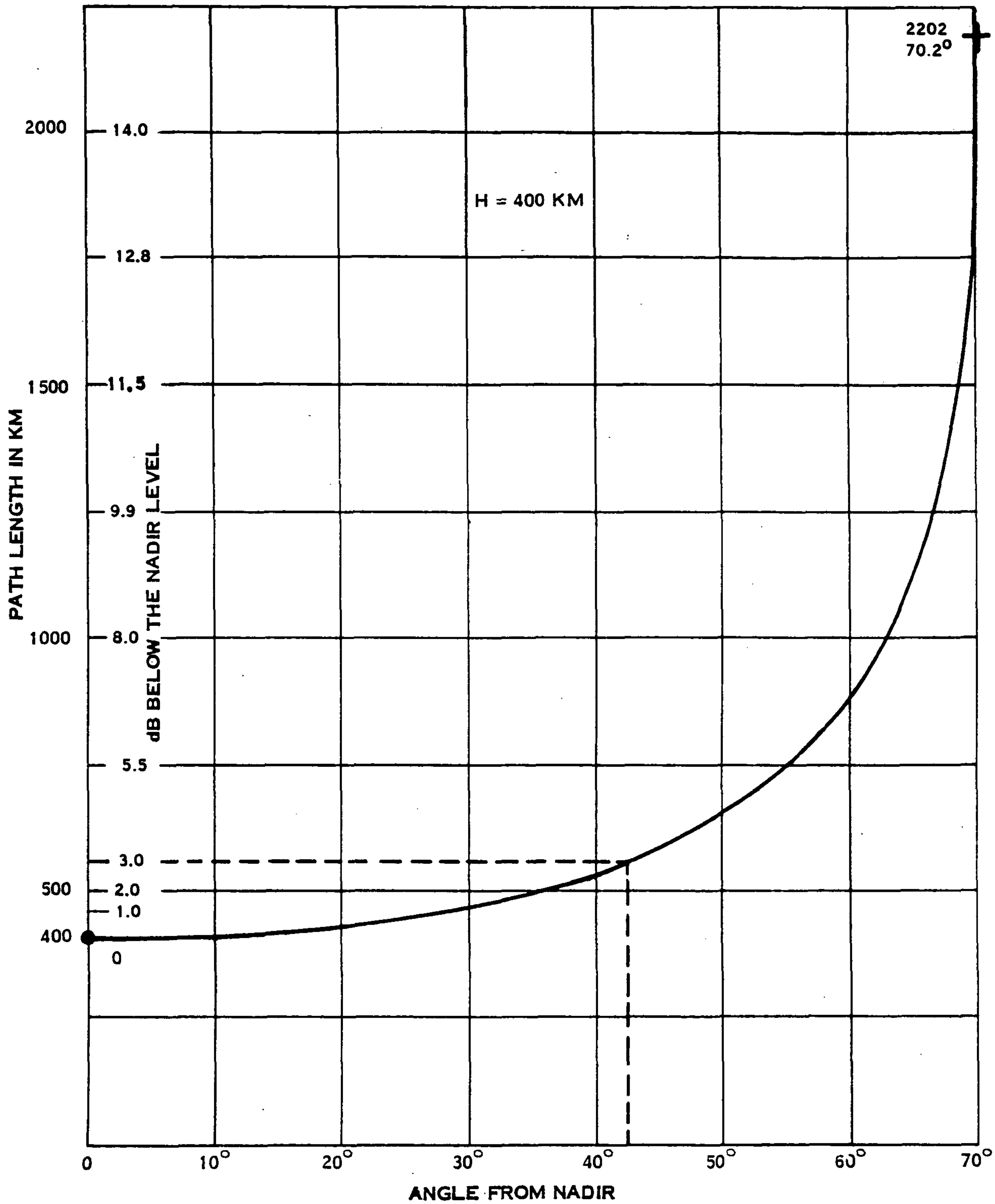


Figure 2-12. Satellite to Earth Path Length Variation

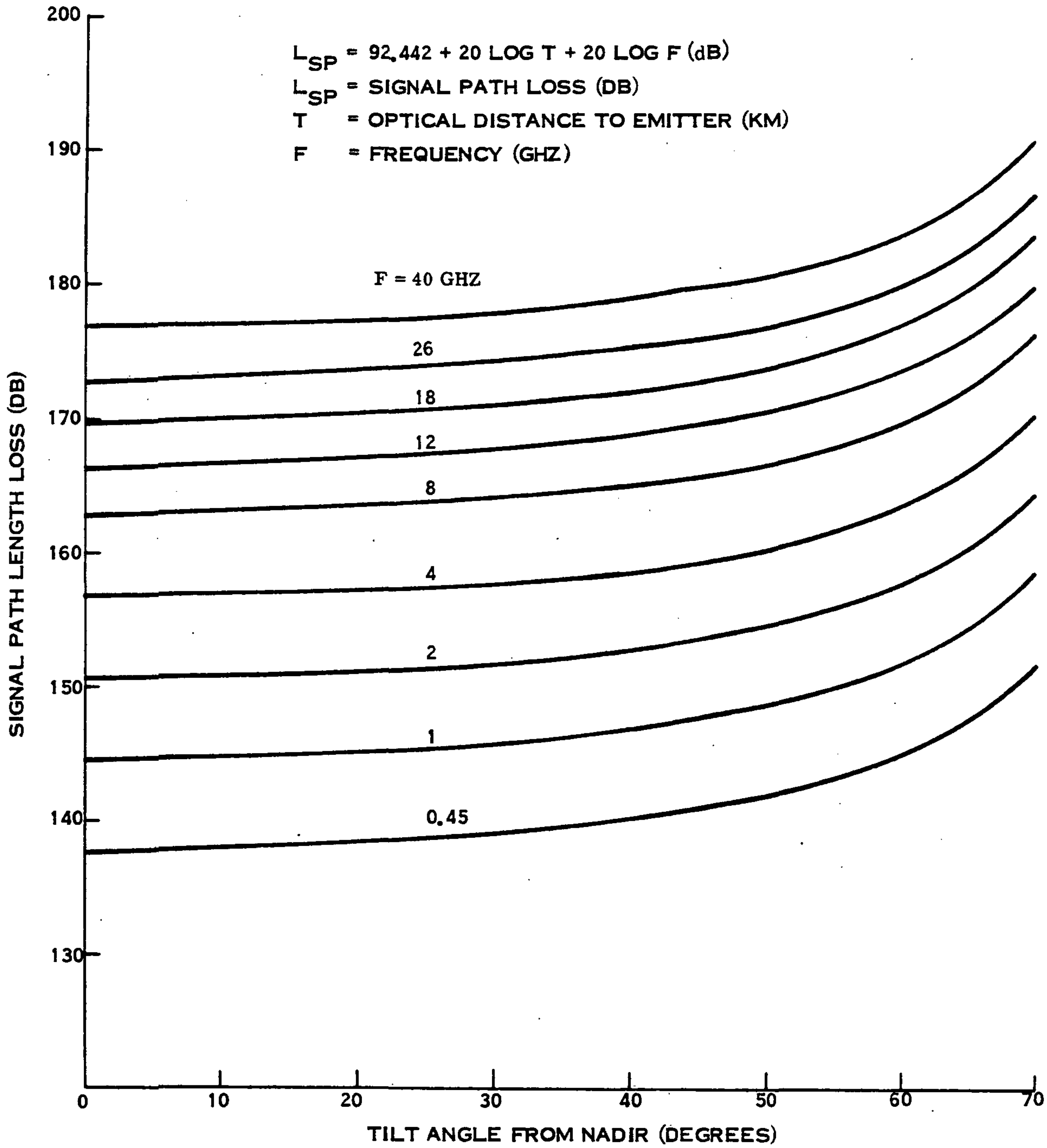


Figure 2-13. Signal Path Length Loss vs. Antenna Tilt Angle From Nadir

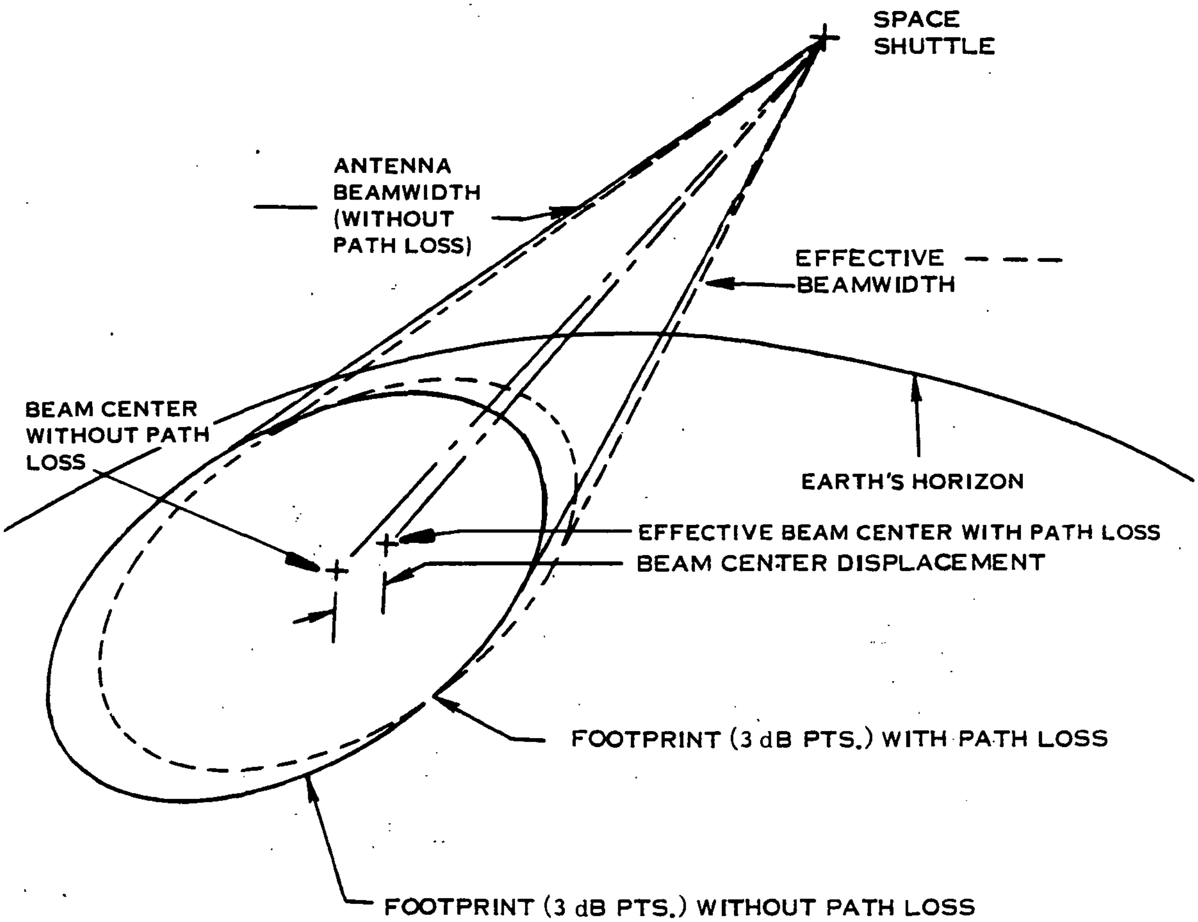


Figure 2-14. Footprint Configurations of the EEE Radiation Beams

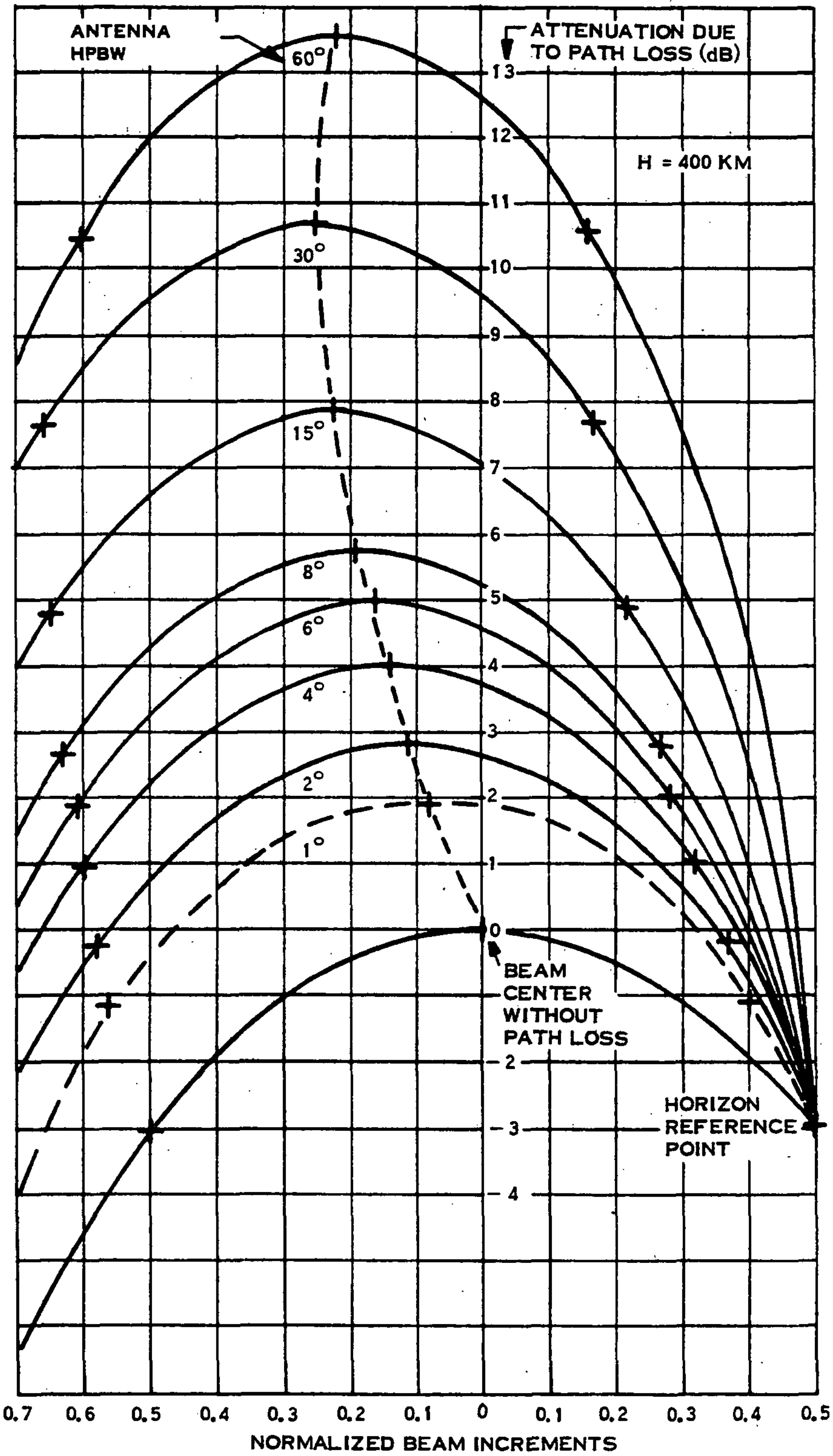


Figure 2-15. **Effective Beam Shift as Function of Beamwidth (With 3 dB Beam Edge at Horizon)**

As shown by the figures, the change of the beamwidth and its footprint on earth is a function of the tilt angle from nadir. This results in a shift of footprint toward nadir as shown in Figure 2-14. Maximum distortion of the beams and maximum shift of beam axes of radiation occur near the horizon. The distorted horizon beams are shown in Figure 2-15 in a normalized form, with antenna beam edges directed to the horizon line. It can be recognized in Figure 2-15 that the distorted beams maintain their symmetry around their new center of radiation. Using the ratio of the beam shift angle to the HPBW as a normalized beam pointing error, a chart for the normalized beam pointing error as a function of beamwidth is shown in Figure 2-16. Figure 2-17 shows the normalized beamwidth in the plane of maximum distortion, as a function of the beam pointing angle from nadir. These charts were generated by a computer program which seeks the peak level of radiation and the new 3 dB points as a function of the orientation angle of the beam.

The major elongation and distortion of the footprint occurs near the horizon in the plane passing through nadir. This distortion has its maximum value when the beam is directed with its upper 3 dB edge slightly above the horizon. The footprint major elongation is shown in Figure 2-18 as a function of the effective* beam depression angle below the horizon. In Figure 2-19, the footprints are shown for 4 concentric beams (in the range between 2° and 8°) with the 8° beam 3 dB edge at the horizon. This figure shows the projected 3 dB points of the beams. When Figure 2-19 is compared with Figure 2-7 it clearly brings out the advantage of shifting the effective beam centers, i.e., corrected for path loss, for coverage of areas near the horizon. However, it should be noted that shifting of the antenna beam centers in order to direct the 3 dB beam edges to the horizon is not really effective for horizon scanning. Figure 2-20 demonstrates this effect. In this figure the footprints of the 2° and the 4° beams are shown, with and without the path loss correction factors. These two beams are pointing with their edges at the horizon. It can be easily seen in this figure that the shifting of the beam centers complicates the configurations of the coverage areas and hence the analysis for locating the radiation sources.

*The effective beam tilt angle and the effective beamwidth are used to indicate the direction of the beam and it's beamwidth when taking the space attenuation factor into consideration.

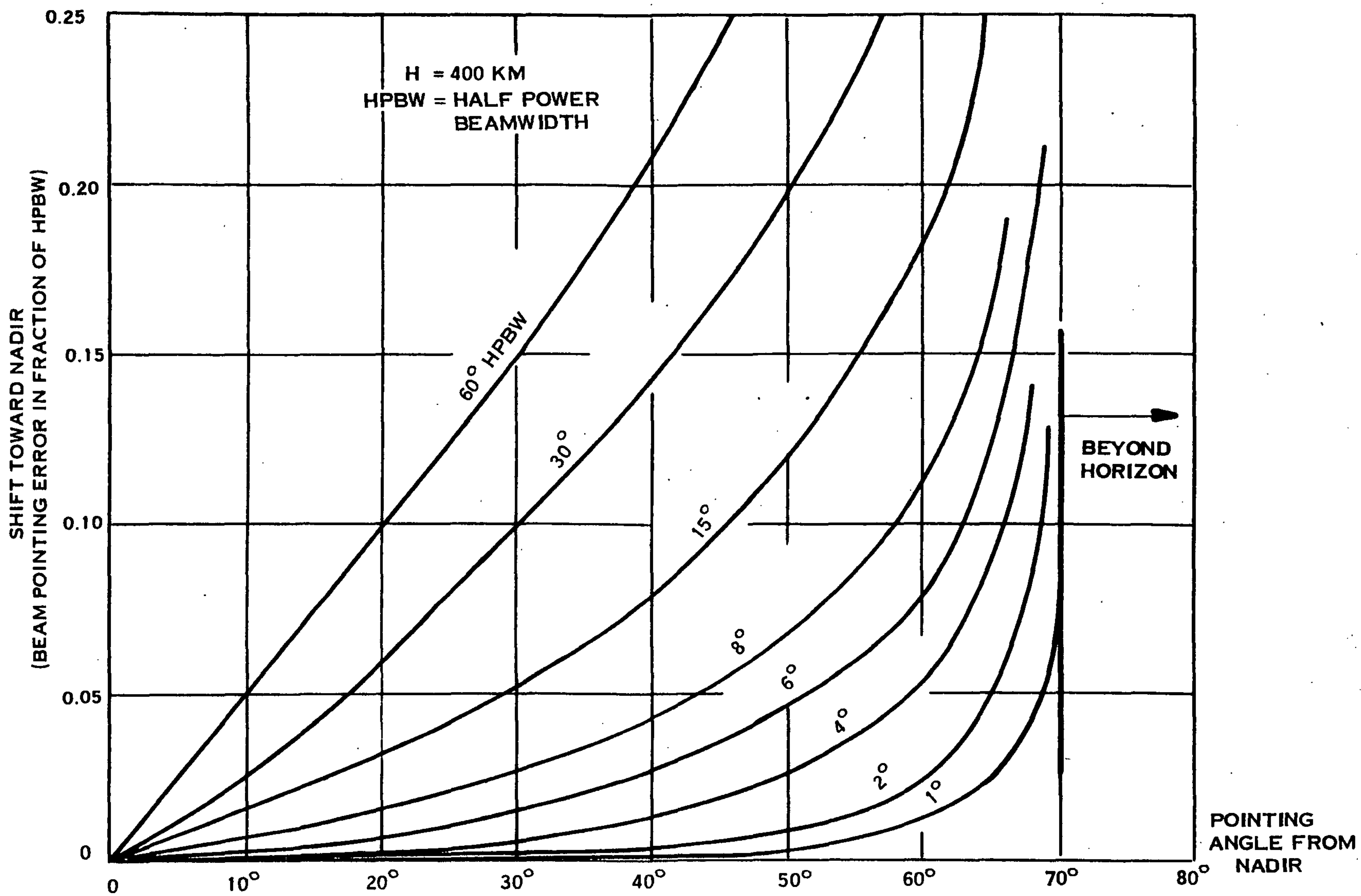


Figure 2-16. Beam Pointing Error

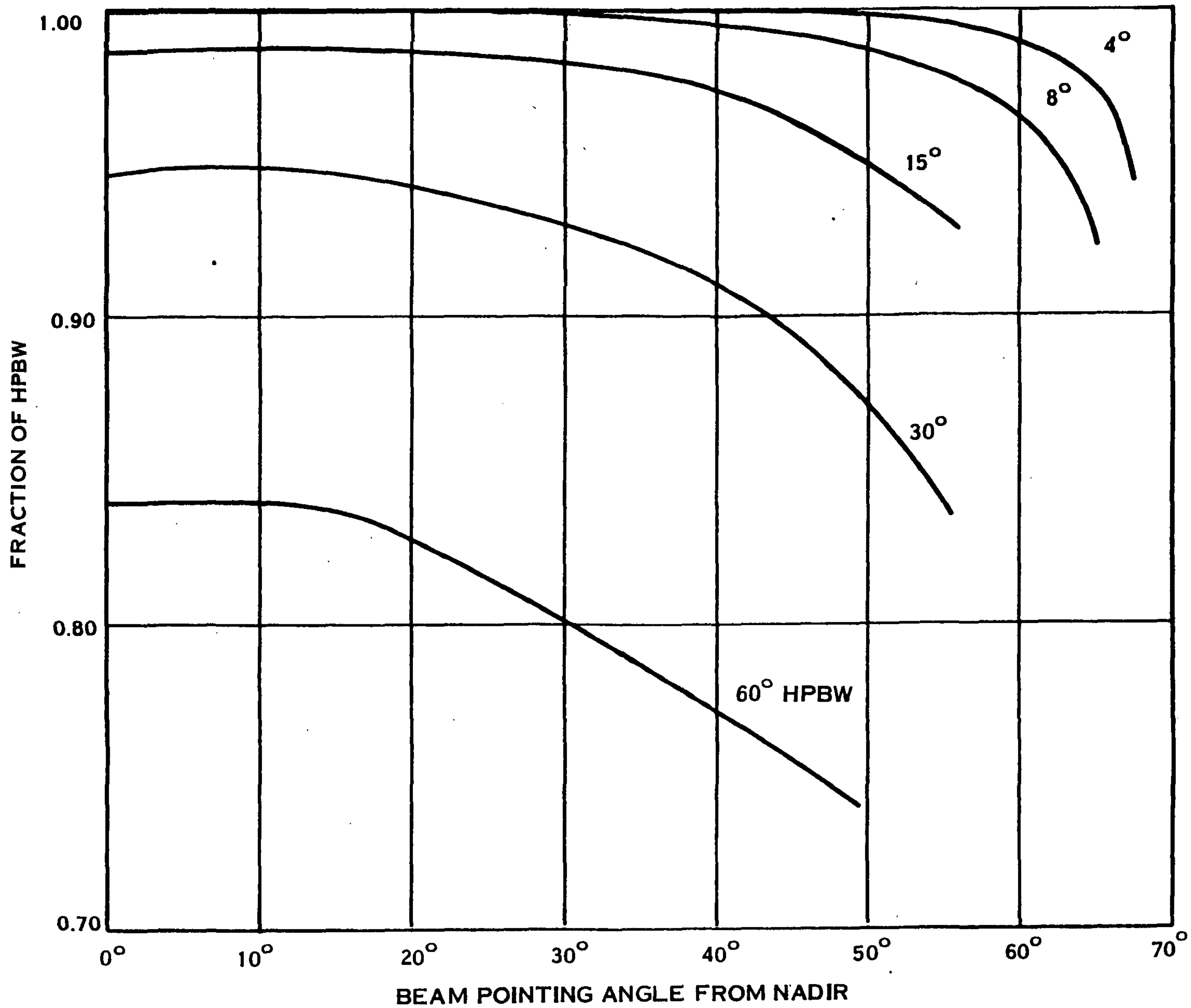


Figure 2-17. The Effective Beamwidth as Function of Pointing Angle

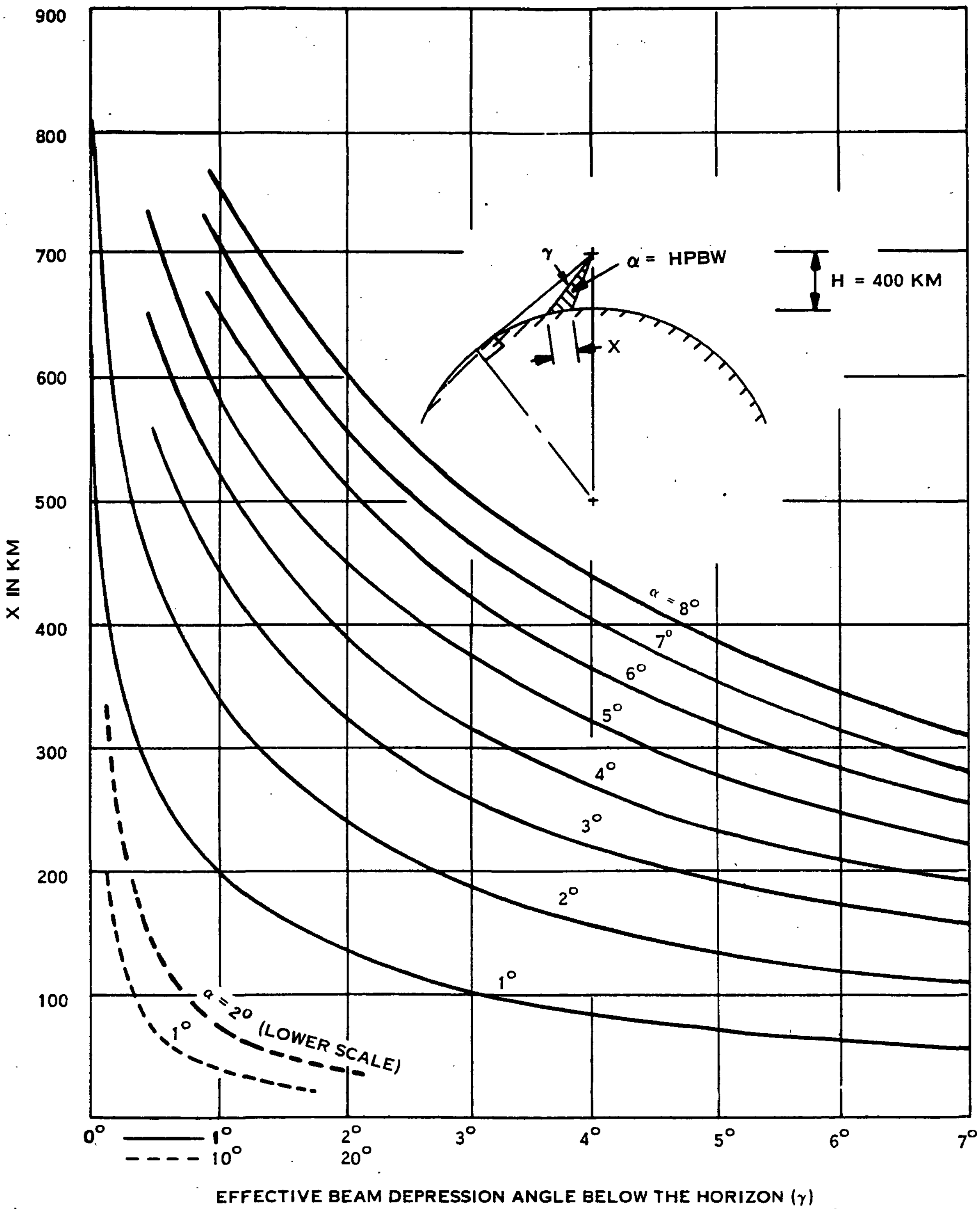


Figure 2-18. Maximum Extent of the Footprint (X) with Beam at a Depression Angle β Below the Horizon

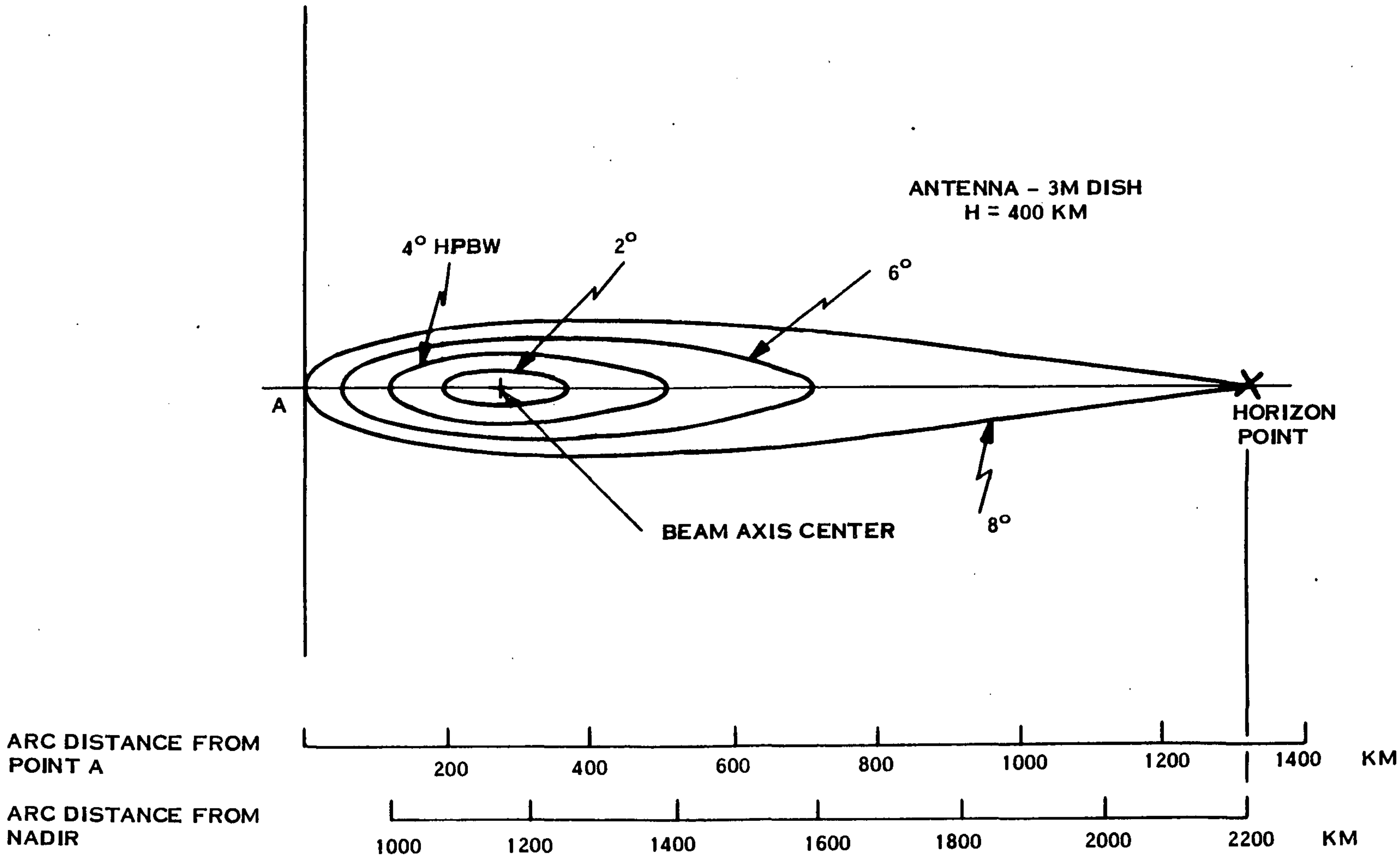


Figure 2-19. Example of the Footprint of Concentric Beams

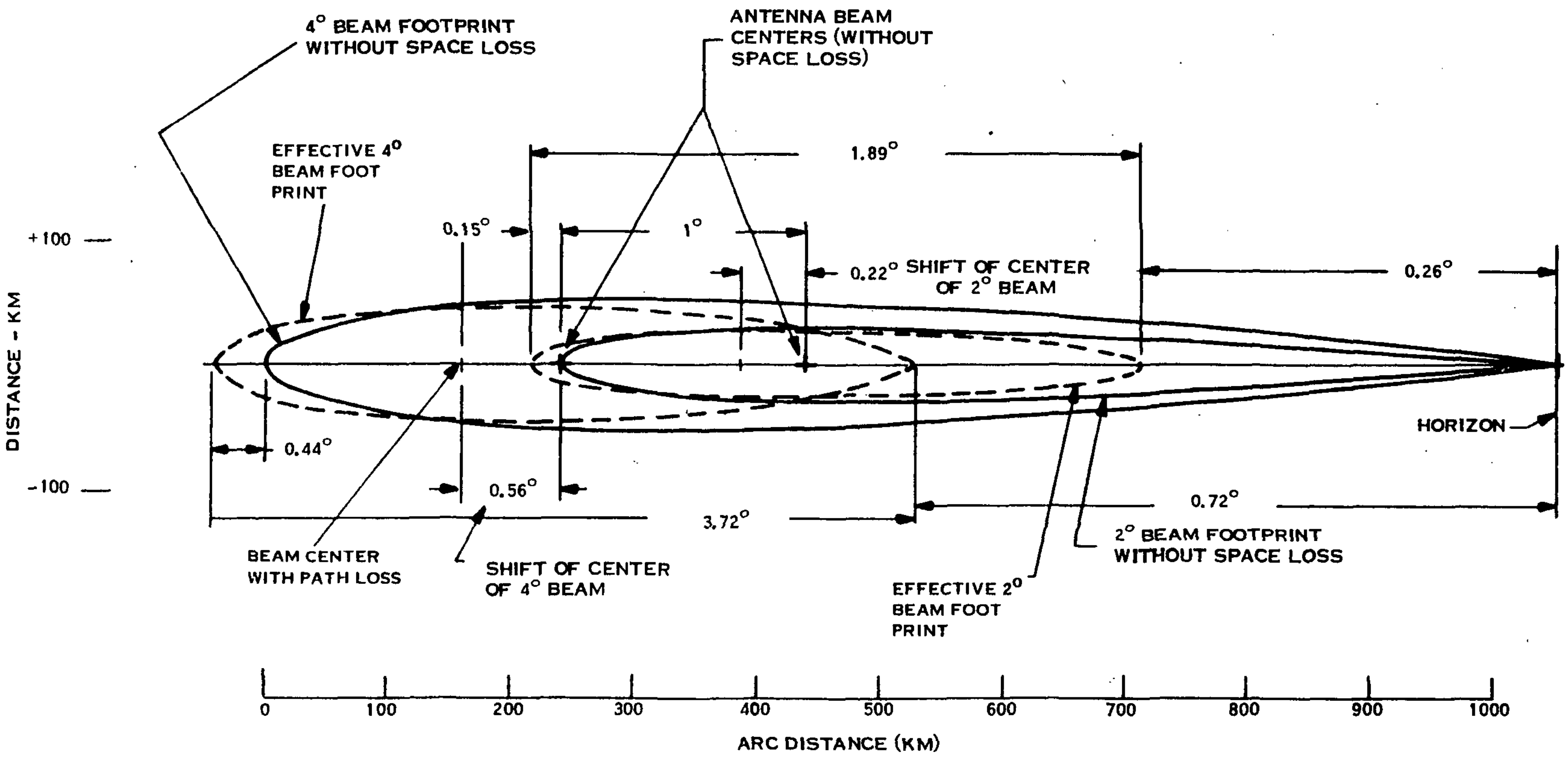


Figure 2-20. Footprints of 4° and 2° Beams with 3 dB Beam Edge at the Horizon

In the search for a technique which would simplify the analysis of the antenna footprints at different frequencies, the following steps have been considered.

1. It has been found that the path length attenuation factor yields footprint configurations similar to those of Figure 2-7 for horizon scanning. These footprints are shown in Figure 2-21. The shift of the axis of radiation of each beam simulated the desirable staggering configuration of Figure 2-7. At the same time horizon signals are received by the positioning of the beams above this horizon. The footprints of the 15^{o} beam and the 1^{o} beam, however, stop short of the horizon line. This situation is not expected to be of serious implications because of the uncertainty of the propagation path near the horizon.

2. When pointing with the concentric beams of the MMAP/EEE antennas to other directions further below the horizon, the eccentricities of the footprints are reduced from the values of Figure 2-21. This results in a configuration of footprints which is similar to the configuration of Figure 2-19. The effective pointing of the center of peak radiation may be easily evaluated from Figure 2-16. Such a correction factor needs to be included in the calibration of the whole system as a function of the pointing angle from nadir, the operating frequency, and the antenna which handles this frequency.

The previous analysis proved the adequateness of using the simple concentric beams of the EEE antennas for pointing and scanning without correction factors at all of the frequencies (at and near the horizon) as well as the adequateness of using these beams with specific pointing correction factors (which are frequency and antenna type dependent) for angles below from the horizon. Typical footprint configurations are shown in Figure 2-22 for a 15^{o} beam at different orientation angles from nadir. Figure 2-23 shows the footprints of the 3m dish and UHF 3m array as projected on the earth.

The footprint analysis presented above provides a base to examine MMAP/EEE antenna scanning schemes, especially near the horizon. The results of this study and additional scanning requirements are the subject of further discussions in the following sections.

2.2.4 EEE SCANNING REQUIREMENTS

Analyses were performed in the previous sections to determine the footprints of the MMAP/EEE antennas. These analyses are used in this section to analyze the antenna scanning requirements. Figure 2-24 illustrates the proposed scanning modes. A summary of the advantages and disadvantages of these scanning modes is shown in Table 2-3 and discussed in the following paragraphs.

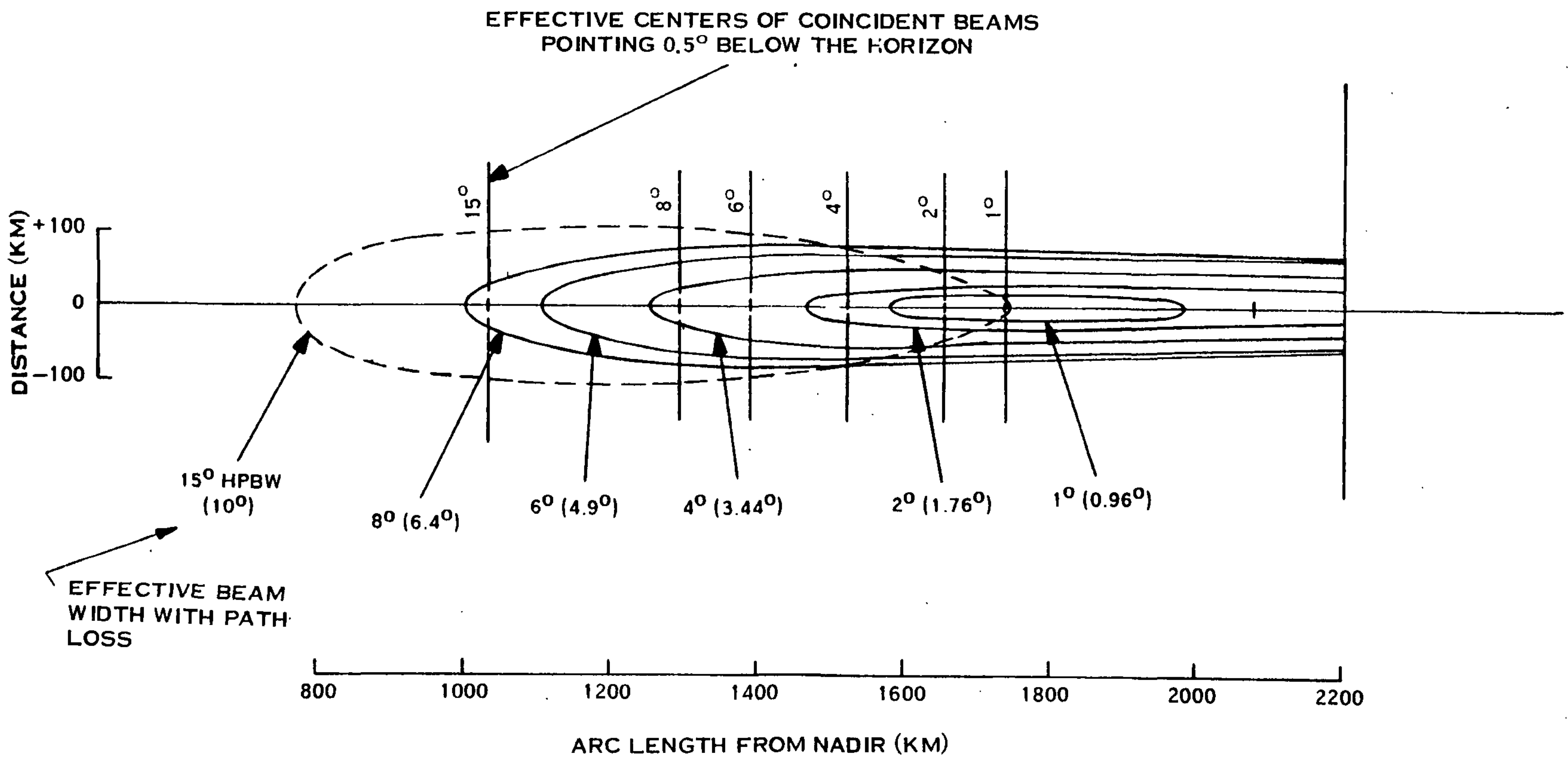


Figure 2-21. Effective Footprints of the Beams of Figure 2-19 With Their Center of Radiation Directed 0.5° Below Horizon

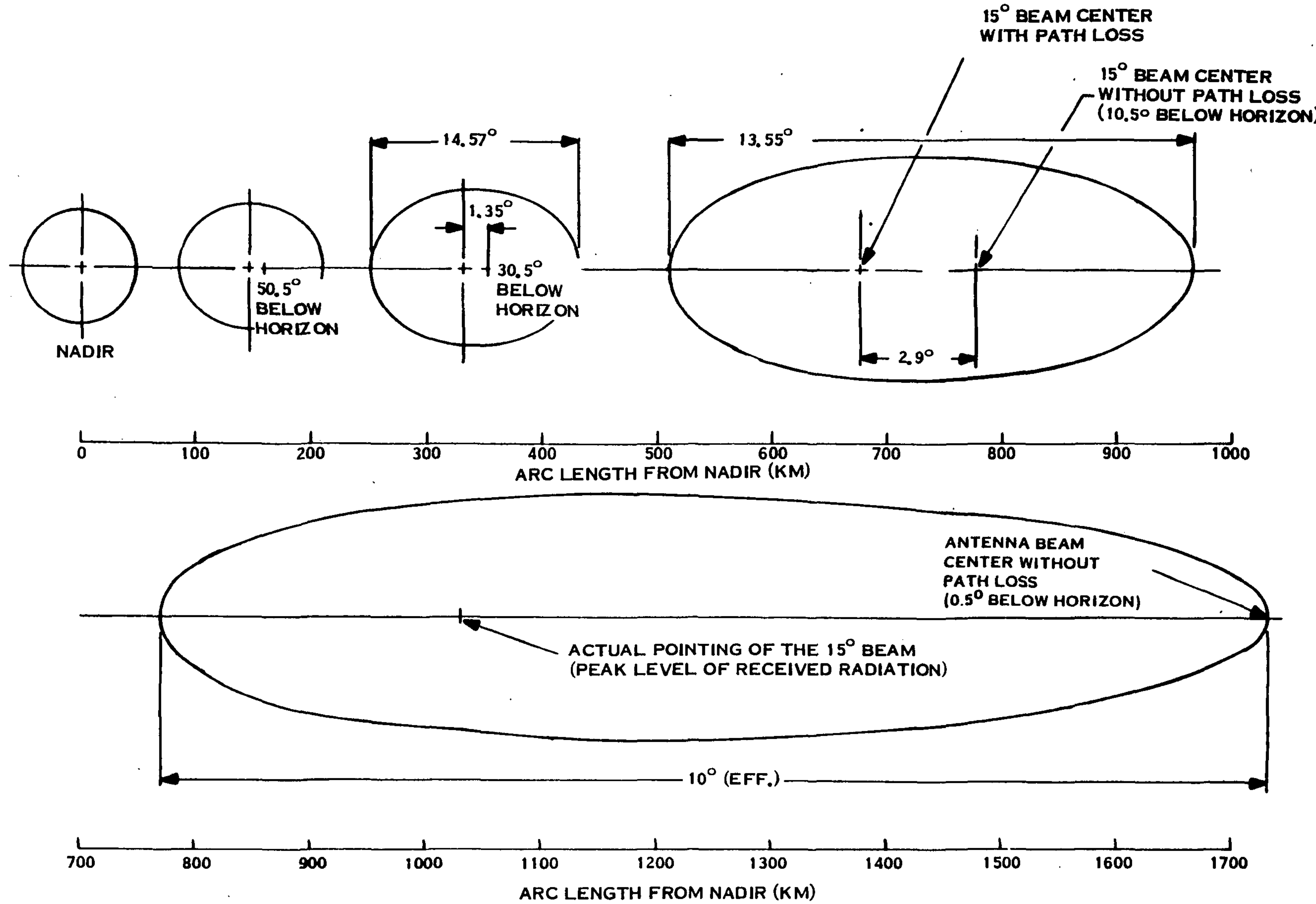


Figure 2-22. 15° HPBW Footprints as Function of the Beam Pointing

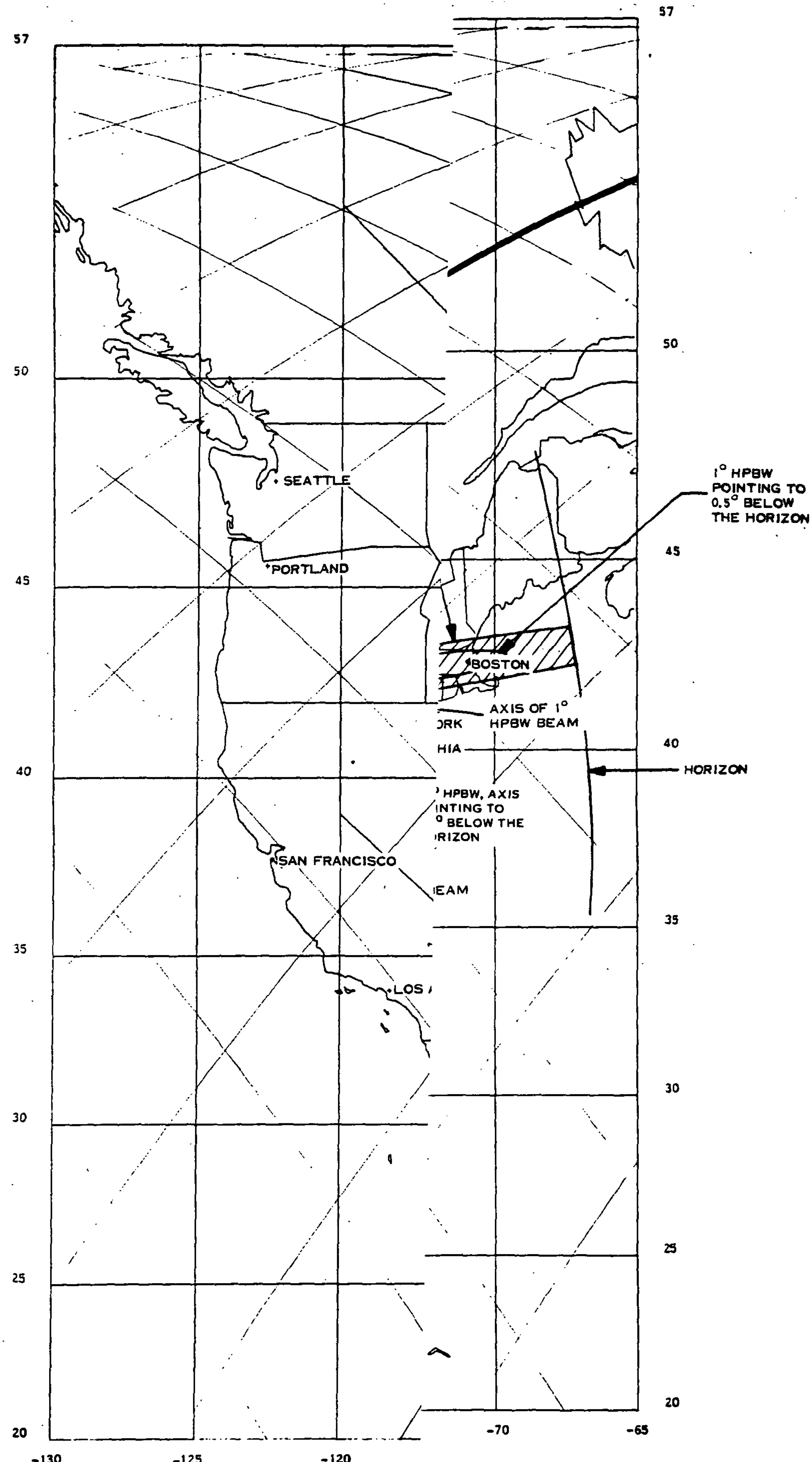


Figure 2-23. MMAPMEEE Antenna Footprints for 3m DISH and 3 x 3m Array

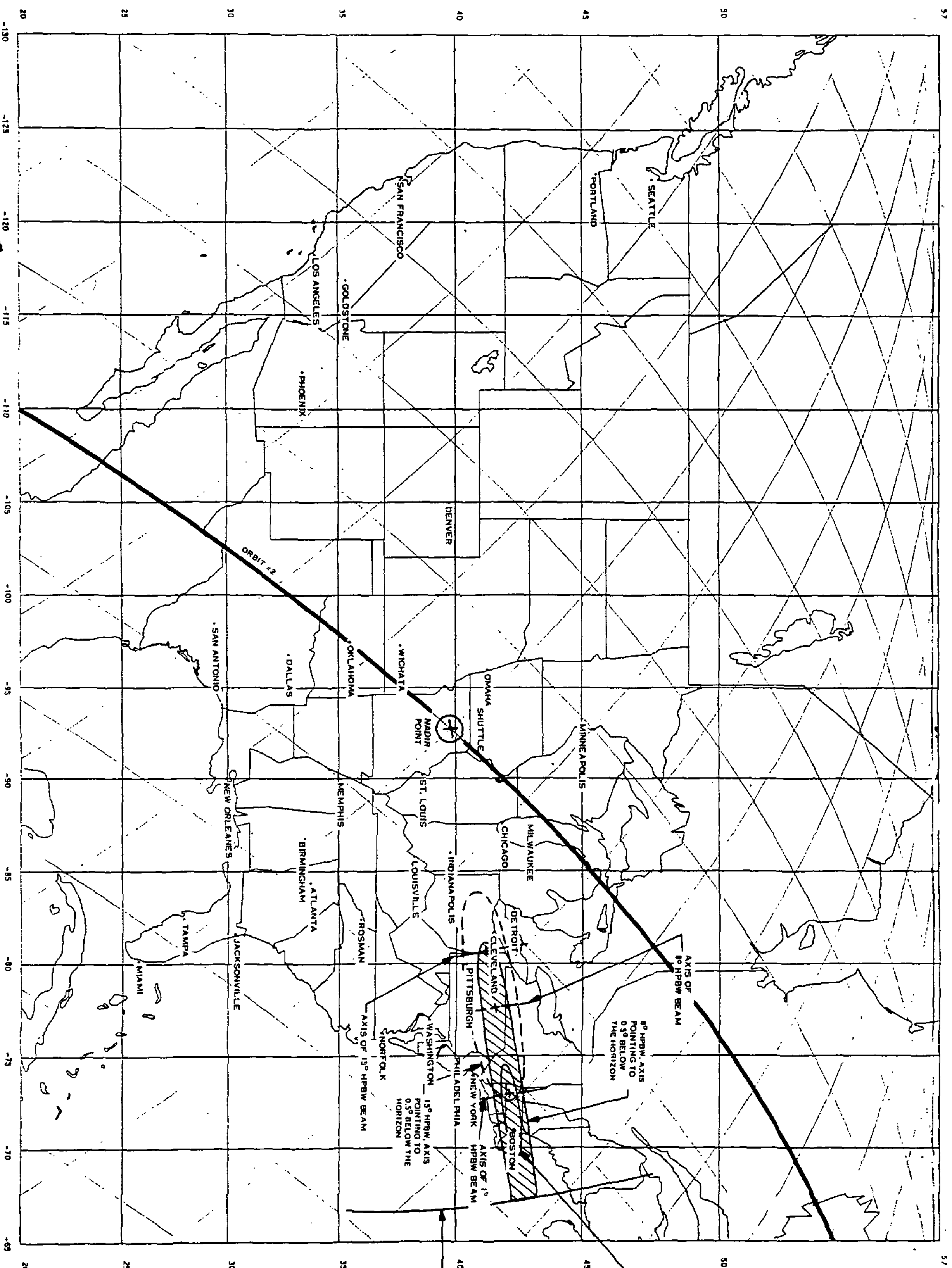


Figure 2-23. MMAPMEEE Antenna Footprints for 3m DISH and 3 x 3m Array

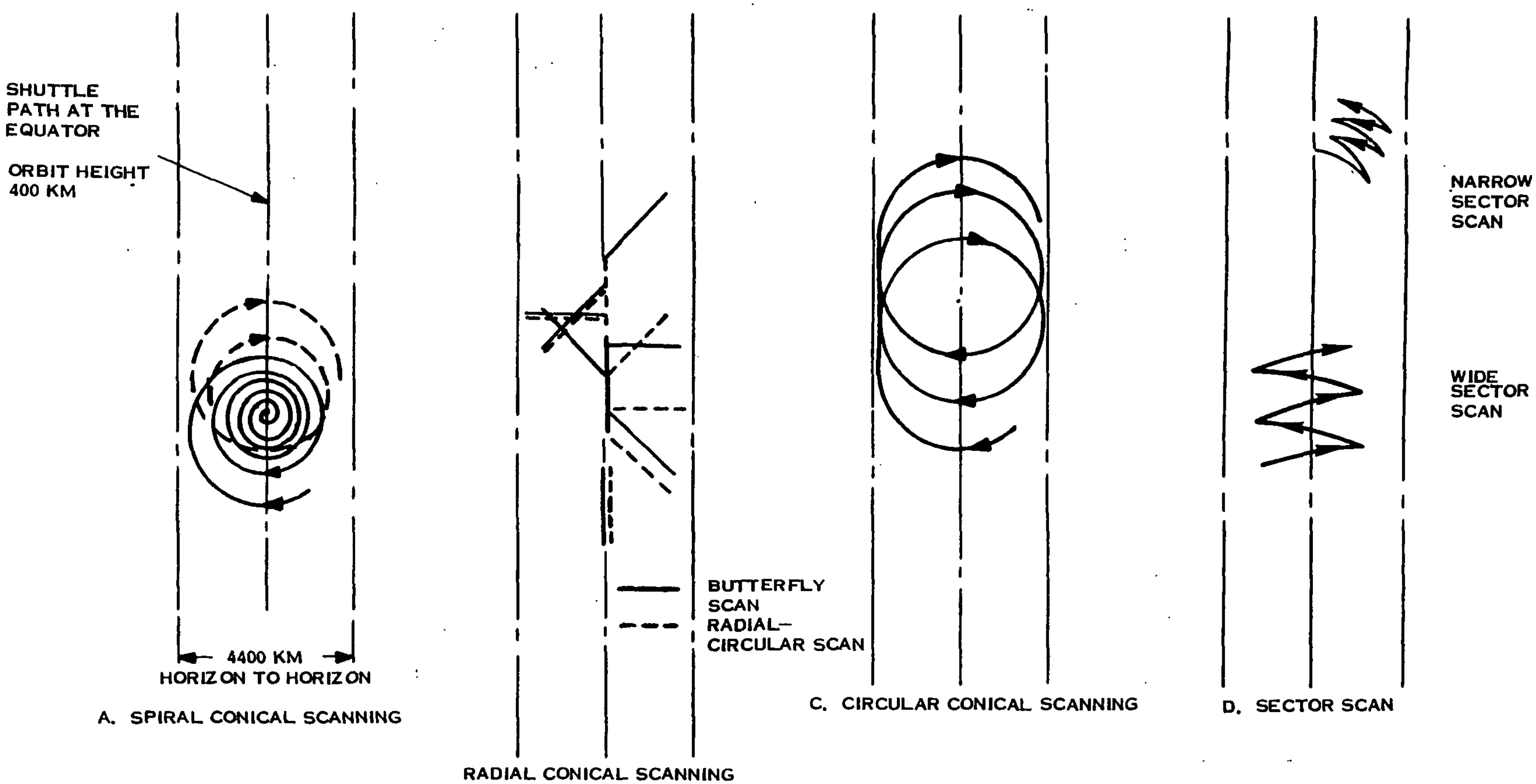


Figure 2-24. MMAP/EEE Antenna Scanning Modes

Table 2-3. Exploration of Scanning Techniques

Type of Scan	Main Purpose	Advantages	Disadvantages
Circular conical scanning of the Horizon[3]	For identification of low elevation angle and terrestrial beams	- Coverage of large areas (45-85% Field of View (FOV) coverage per revolution for areas under the Shuttle for terrestrial beams of 0^{o}-15^{o} elevation) - Simple design technology of antenna feeds - Slow steady scanning rates - Large overlap of beam coverage at both sides of the Shuttle - Long beam dwell time to allow signature study of emitters	- Low geographical resolution for locating emitters - Little coverage of areas near nadir for high elevation emitters
Spiral conical scanning with reversed cycles	For detection of horizontal and elevated radiation beams	- Excellent geographic coverage - Possible overlap of coverage for both elevated and horizontal radiating beams	- High scan speed near the center of the spiral at NADIR - Small dwell time on sources near nadir - High antenna acceleration rates near nadir
Radial conical scanning	For detection of horizontal and elevated beams	- Limited coverage - Possible large overlap of spot coverages	- Complex routine of scanning - High and reversed acceleration rates near the nadir
Dual beamwidth scanning with broad and narrow beams	For complete coverage, especially near nadir	- Allows overlapping coverage at tilt angles near nadir	- Beamwidth switching required - Reduction of sensitivity for widebeam antenna
Sector scan[7]	For detection of radiation beams in a specific angular sector	- Slow scanning rates and accelerations - Investigation of particular sectors for specific elevated beams	- Low probability of detection of many sources away from the scanned sector. - Little probability of detection for emitters of different elevations.
Manual operation	For detection of radiation beams in a specific sector	- Verification of specific mission requirements	- Low probability of detection of many other sources

[3,7] See References 3 and 7

2.2.4.1 Horizon Conical Scanning

Large portions of the earth cap area below the Space Shuttle can be scanned by using the horizon circular scanning mode. This scanning mode is proposed in Reference 3 by the University of Pennsylvania. The coverage is more than 40 percent of the area of the earth's cap for the narrowest beamwidth of radiation. This mode of scanning is the most promising technique to map large areas of the surface of the earth at the lowest scanning speed, and yet achieve the largest probability of detection for most of the radiating sources. These sources include radar installations, line of sight communications and power from high elevation angle satellite earth stations terminal antennas.

The circular horizon scanning, when adjusted for proper overlap at the highest frequency, yields a larger overlap of scan coverage at lower frequencies. The large overlap is due to the largest footprints at these frequencies. Fortunately this large overlap at lower frequencies increases the probability of detection for low frequency radiators. The scanning speed for proper overlap at highest frequency (with a narrowest beamwidth of 0.8^o) is approximately 4^o/sec, whereas with the proper overlap of the largest beamwidth (15^o at 0.5 GHz) it is approximately 2^o/sec. Hence, the large spread of frequencies and beamwidths is bridged by small spread in the required speed of scanning. The range of elevated angles of the detectable terrestrial beams may be obtained from Figure 2-8 (and by making use of the angular extent of the footprints of Figure 2-21), which indicates an elevation range of 0^o - 6^o for the narrowest beam and a range of 0^o - 23^o for the widest beam (15^o beam) at the lowest frequency. The wide range of elevation angles for the detected terrestrial beams at low frequencies is compensated by large scanning overlap at these frequencies which enhances the detection probability of these sources.

The achievable capability of detection of high signal levels by horizon scanning (due to the large probability of beam to beam interception when detecting low elevated high power beams) dictates large dynamic ranges for the MMAP/EEE receivers and necessitates specific time responses of these receivers in order to clearly detect the fast

scanning beams, such as those of pulsed radar. The large dynamic range is needed to identify low power sources. It increases, however, the probability of identification of sources detectable through the radar side-lobes or at low levels of their radiation beams.

An illustration of the circular conical scanning of the horizon, which represents the swath of the center of the beam is shown in Figure 2-24-c. This indicates that the circular horizon scanning covers an area extending to the third nadir track line of the planned orbits (for a 400 km altitude). The large coverage of this mode scans most of the United States during one revolution as can be interpreted from Figure 2-23. It can be seen in Figure 2-24-c that a source can be seen at least twice from two successive orbits which means that this source can be seen at least 6 times in one day from different look angels.

2.2.4.2 Spiral Conical Scanning With Reversed Cycles

This scanning mode is intended for completion of scan coverage in order to detect high elevated terrestrial beams. The scanning spiral of this mode is illustrated in Figure 2-24-a. Due to the fast shrinking size of the antenna footprints when the beam points to directions below the horizon (as can be seen in Figure 2-18) the scanning speed at nadir (for a narrow beam of 1^{o}) is approximately 360^{o} per second, which is not realizable without elaborate gimbal and attitude control designs. On the assumption that 60^{o} per second is a feasible maximum speed of rotation, the minimum size of the usable antenna footprint should be six times its size at nadir. This footprint size is approximately 43 km, which means that the maximum scanning for complete overlap is achievable at approximately 10^{o} below the horizon, i.e., 60^{o} off nadir. This means that it is not possible without elaborate mechanical design considerations to detect large elevated terrestrial beams with elevation angles between 23^{o} and 90^{o} without loss of coverage for areas below the Space Shuttle. A partial solution for this problem is to continue the spiral conical scanning till nadir at the maximum possible speed of 60 degrees per second, as illustrated in Figure 2-24-a. When reaching the maximum scanning speeds at the inner regions of the spiral the spots of the pattern which are

not covered due to slower than required scan rates, may partially be covered when the scanning spiral spins back from nadir to horizon. Consequently the detectability of many radiating sources would rely heavily on radiation received through the side-lobes and low levels of the radiation patterns.

2.2.4.3 Radial Conical Scanning

Due to an anticipated small number of radiating terrestrial sources at high elevation angles, especially above 10 GH, it may be interesting to thoroughly investigate selected segments of the earth's cap. For this special purpose the radial conical scanning of Figure 2-24-b may be used. This mode can be described as a radial swing of the beam from nadir to horizon with broad return loops near the horizons. The radial loops of the pattern may be formed by continuous motion from horizon to horizon as described by the solid center lines of the pattern, or formed by reversed radial motion at nadir as described by the dotted center lines. The latter technique involves large accelerations and retardations at nadir and achieves the same coverage as the former technique. Therefore, it is preferable to use the former technique which may be called the "Butterfly Radial Conical Scanning." In this type of scanning the areas near nadir as well as the upper left area of Figure 2-24-b are thoroughly investigated.

2.2.4.4 Dual Beamwidth Scanning

In order to avoid the problems of lack of complete coverage when using the spiral scanning or the radial conical scanning it is possible to employ broad beams to handle areas near nadir. For this mode of operation 30^{o} to 60^{o} HPBW Beams are adequate. One possible arrangement is to scan at the horizon for good footprint overlap using the narrow beam antennas and obtain complete coverage by using the broad beams around nadir. Use of broad beam antennas, however, is accompanied by a reduction of sensitivity, which is not a serious factor because most of the high elevated beams are of high EIRP levels. Examples for these sources are the future Ku-band transmitters for domestic and broadcasting satellites. These powerful transmitters might be detected as well through the side-lobes of the high gain antennas. For these reasons it is

preferable to conduct the spiral conical scanning as previously explained until the highest rotation speed is reached and the antenna beamwidth for a particular frequency is reduced below that beamwidth which allows full geographical coverage. For higher frequencies full coverage could be achieved by broadbeam antennas. This guarantees complete overlapping of coverage for frequencies using the narrowbeam antennas near the horizon and the broadbeam antennas near nadir.

2.2.4.5 Sector Scan

This scan mode is illustrated in Figure 2-24d. The beam pointing oscillates around a particular line along the space shuttle track or parallel to this track. The amplitude of oscillation is to be adjusted so that it would comply with specific geographical coverage requirements. Complete coverage of a particular strip around the shuttle track necessitates specific scan velocity which is function of the location of the scanned strip relative to the shuttle track and the beamwidth of the radiation beam. The limited scan coverage of this mode makes it possible to locate specific emitters of particular low angle elevated beams with minimal gimbal drive requirements. The maximum angular velocity of the gimble is

$$V_m = \theta_m \left(\frac{2\pi}{\tau}\right)$$

and the maximum angular acceleration is

$$\alpha_m = \theta_m \left(\frac{2\pi}{\tau}\right)^2$$

where θ_m is the maximum amplitude of the angle off the shuttle track and τ is the time period of one oscillation.

2.2.4.6 Manual Operation

This capability allows the Shuttle mission specialist to have manual control to investigate specific interesting emitter locations. It also gives him the capability to switch to any of the previously explained scan modes within specific limited sectors.

The choice of any of these modes is determined by many factors. Investigation of a known emitter and antenna positioning for beacon acquisition and track are examples of the need for manual operation.

2.2.5 ATMOSPHERIC PROPAGATION EFFECTS

Typical sources of radiation which are to be identified by the MMAP/EEE antennas are illustrated in Figure 2-4. It is easy to see that the obvious sources of uncertainty for locating the direction of radiation are due to reflections from ground (or sea) as well as beyond the horizon refracted and ground bound creeping waves. In addition, atmospheric refraction will cause multipath effects and scintillation which increase the uncertainty of identification of the radiating sources in concern of locations and EIRP levels. These uncertainties are maximum for sources near the horizon. Typical illustrations of radio ducting and refraction effects are shown in Figure 2-25. It can be seen that the MMAP/EEE antennas would identify sources of radiation nearer than the horizon as well as beyond the horizon. Preliminary estimates of the range difference between the geometric horizon and the refraction radio horizon is in the order of a hundred kilometers which is negligible relative to the footprint size at the horizon.

From the point of view of the EEE objectives, of spectrum utilization, this effect is not serious, since the footprint of the antenna has its greatest elongation near the horizon and it would be difficult to pinpoint the location of a source within this footprint under any circumstances.

The serious effect of having a duct is that the EIRP level of signals propagating to space (away from the duct) would be smaller than the actual EIRP level of the ducted sources.

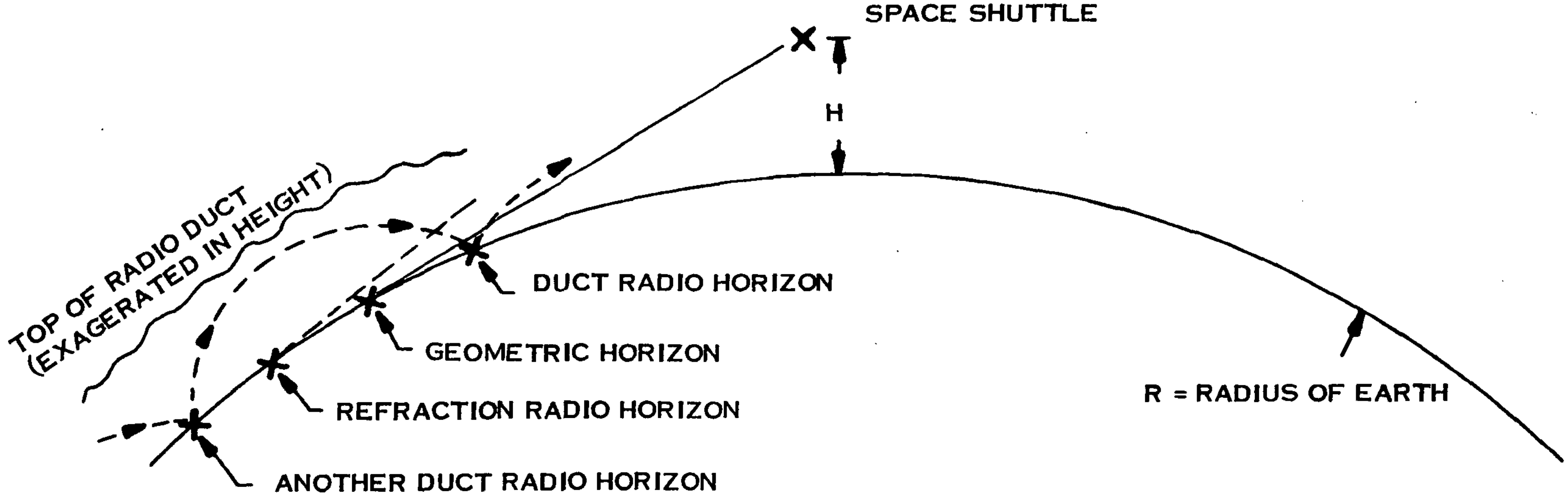


Figure 2-25. Refraction Effects of Radio Waves

2.3 SYSTEM SOFTWARE AND DATA PROCESSING ANALYSIS

2.3.1 INTRODUCTION

Digitized data output from the MMAP/EEE sensors must be formatted and recorded for data processing (DP) on the ground. Any such DP system has two logical constraints: the data input to the system and the information desired by the ultimate users. In addition, there are technological constraints which impact systems having large volumes of data or high data rates.

Processing is of two "types": on-board processing (aboard the shuttle) and ground processing. On-board processing must be near-real time due to data volume constraints. Ground processing, which is done at an appropriate DP center, must be fast enough to generate timely and useful output. It is customary to think of ground processing as involving two steps: pre-processing and extractive processing. The former converts data into a form directly useful for investigative study. The latter is the automation of the studies.

For convenience, this analysis is divided into the following sections:

1. Sensor Data Rates
2. Systems Assumptions
3. On-Board Processing
4. Ground Processing
5. Hardware Implementation
    a. Aboard Shuttle
    b. On the Ground
6. Future Investigation needs

2.3.2 SENSOR DATA RATES

It is assumed that the sensors will cover the frequency bands as shown in Table 3-9 and will operate serially, i.e., only one frequency sweep will be in progress at any instant. Band A will operate at 1 KHz resolution only when tracking; other bands will not operate at this time. Band B has three sub-bands, only one of which will be on when the system is operating. The on-board data handling system must be capable of handling peak load data rates for short periods and "worst-case" mission volume. "Worst case" refers to the various resolution requirements that can be imposed on each of the bands and includes the choice of the three sub-bands of Band B. The three sub-bands are denoted B1, B2 and B3 in order of increasing frequency. The worst case mean and maximum data rates are also vital for determining ground process loading. Table 2-4 is constructed from Table 3-9 and contains bandwidth, resolution and sweep times taken directly from that table. The mean trigger rate is an order-of-magnitude estimate of the percent of frequency cells in each band with S/N (signal-to-noise ratio) above a designated threshold. Other parameters used in Table 2-4 are:

1. No. of data cells = bandwidth/resolution cell
2. Max data rate in cells per second = No. data cells/sweep time
3. Max data rate in Mbps = 80 x max rate in cells per second, where 80 = no. bits per data cell
4. Max megabits per sweep = max data rate (Mbps) x sweep time
5. Mean megabits per sweep = trigger rate x max megabits per sweep
6. Mean data rate = total mean megabits per sweep/total sweep time
7. Max data rate = total max megabits per sweep for the total sweep time

Note that totals do not include items in parentheses.

2.3.3 SYSTEMS ASSUMPTIONS

Table 2-5, "System Processing Guidelines," summarizes the basic characteristics of the envisioned system. The list is not all inclusive. Rather, it is meant to give a feeling for the data to be handled by the system and the nature of the system's operation.

Table 2-4. Worst Case Sensor Data Rates for EEE With Serial Frequency Sweeps

Freq. Band	Bandwidth (GHz)	Resolution (MHz)	No. of Data Cells (K-Cells)	Sweep Time (Sec)	Max Data Rate (K-Cells/Sec)	Max Data Rate (Mbps)	Max Mega-Bits Sweep	Mean Trigger Rate (%)	Mean Mega-Bits per Sweep
A (Track)	(.1)	.001	(100.)	(10.0)	10	.8	(8.00)	-	-
A	.1	.02	5.	.375	13	1.1	.40	10	.040
B1	.5	.02	25.	.3	83	6.6	1.98	10	.198
B2	.5	.2	2.5	(.25)	10	.8	(.2)	10	(.020)
B3	2.0	1.0	2.0	(.4)	5	.4	(2.)	10	(.200)
C	4.0	.2	20.	.4	50	4.	1.6	1	.016
D	4.0	.2	20.	.4	50	4.	1.6	1	.016
E	6.0	1.0	6.	.6	10	.8	.48	.01	.000
F	8.0	1.0	8.	.4	20	1.6	.64	.01	.000
G	8.0	1.0	8.	.4	20	1.6	.64	.01	.000
H	6.0	1.0	6.	.3	20	1.6	.48	.01	.000
Total	39.1		102.5	3.175			7.82		.263

Mean Data Rate = 83 Kbps

Max Data Rate = 2.5 Mbps

Table 2-5. MMAP/EEE System Processing Guidelines

- Data to be Captured Aboard Shuttle
  - OP of Channels A-H (ref. Table 3-9)
  - Mean Data Rates: A, B = 10%; C, D = 1%; E-H = .01%
  - Time from shuttle master clock
  - Shuttle attitude changes
  - AZ, EL of sensors relative to shuttle attitude, position
- Data to be Made Available on Ground in 7 Days
  - Shuttle ephemeris
- Data Not To Be Captured
  - Sensor position aboard shuttle (constant)
  - Sensor feedback data
  - Calibration data
  - Scanning mode
- Data Record Modes
  - Record on-board and real-time TDRSS relay
  - Record only
  - Relay only
  - Playback: Send recorded data to ground
- Data Handling Capacities
  - 20 Hours/Week at mean rate
  - Preprocessing complete 7 days after ephemeris received for 7-day mission
- Operational Requirements
  - Selectable Graphical/Digital displays in real-time aboard shuttle and at OCC
  - Multiple sensor scan modes
  - Only data above selectable thresholds to be recorded
  - Auto sensor, record, display control
    - Shuttle, OCC Manual Over-Ride
- Flexible Extractive Processing

2.3.4 ON-BOARD PROCESSING

The on-board processing philosophy is to eliminate as much data as possible before ground processing, but to keep on-board processing to a minimum. Historically, satellite data collection systems have had serious bottlenecks at the ground pre-processing stage. The best way to avoid this is to reduce the amount of valueless data reaching the ground. Obviously, all useful data must be kept. This system attempts to do this by:

1. Recording only data with sufficiently high S/N
    a. Adjustable thresholds (trigger levels) are employed
2. Serial frequency sweeping
3. Independent on-off control for each channel
4. Selective resolution
5. Selective scanning modes
6. Not recording non-essential information
    a. Hardware feedback control commands and data
    b. Scanning modes
    c. System conditions such as channel on-off state
7. Clever bit-stream configuration
8. Full automatic and manual system control
    a. Displays to aid manual decision process
    b. Photographic copies of displays under manual control

The decision to minimize on-board processing is prompted by three factors: 1) the high cost of sophisticated space processors including the added weight, 2) decreased flexibility, and 3) decreased reliability. There are two flexibility considerations. A smaller payload can be carried on more and different kinds of missions. If only pre-processed data are available, subsequent investigation of the original data will not be possible. After collection of the data,

it is conceivable that new and specialized investigations will be requested. Although the system is not being designed to accommodate scientific investigation, the system should make specialized investigation possible.

A candidate on-board data processing system for MMAP/EEE is shown in Figure 2-26. This diagram is a functional description and includes the Shuttle Master Clock, the on-board Mission Specialist and the TDRSS link to the ground processing center. The data to be recorded and/or telemetered via TDRSS to the ground are described in the accompanying signal data chart, Table 2-6. Several points should be noted with regard to this chart. The computation in Table 2-4 of mean data rate was based on the assumption of 80-bit data records. That is, only Record 1 was considered. For this to be correct, the mean bit rates from Records 2 and 3 must be negligible compared to the mean bit rate of Record 1, which is 83 Kbps. Record 3, TIME, occurs precisely once a minute and hence has a bit rate of $28/60 \times 10^{-3}$ Kbps. According to current estimates, shuttle attitude changes will be significant enough to require a new attitude description, Record 2, at most once a minute. This yields a Record 2 bit rate of less than $39/60 \times 10^{-3}$ Kbps. Based on these assumptions, the total data rate is the same as Record 1.

Clearly, the number of bits required for any field is just $\log_2$ (unit range/unit size). In Record 1, the interpretation of the frequency field depends on the channel specified in the channel field. A specified channel has a step resolution unit bandwidth, U, and a minimum frequency, F. If n is the (decimal) number of steps in the frequency field, then the recorded frequency is (F + n U). The number of bits needed for the frequency field can be determined as shown in Table 2-7.

2.3.5 GROUND PROCESSING

The ground processing system is designed so that the same near-real time displays and controls available aboard the shuttle are also available on the ground. This makes manual experiment control possible if the sensors are aboard an unmanned satellite or if an on-board Shuttle Mission Specialist is not available.

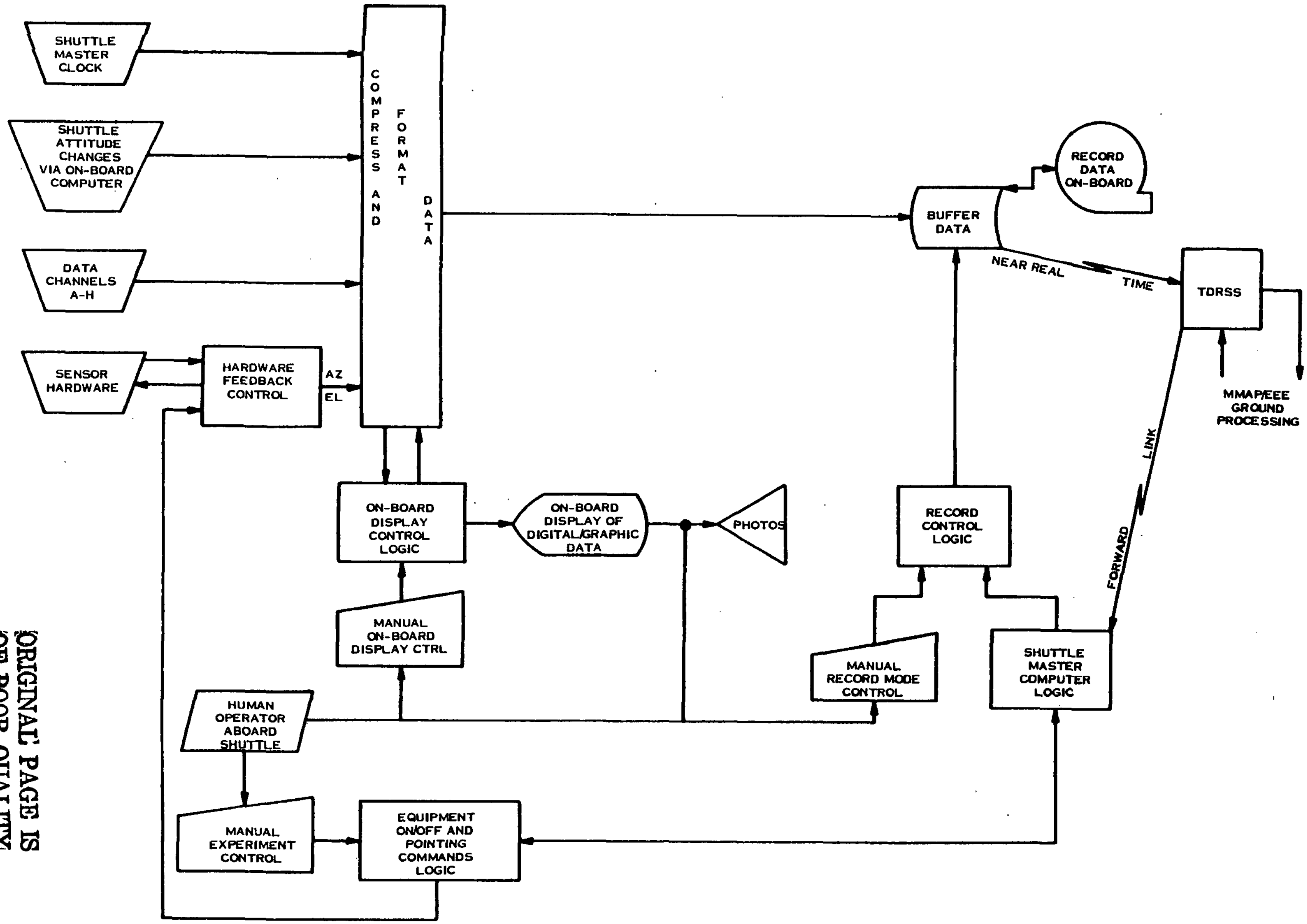


Figure 2-26. MMAP/EEE On-Board Processing

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Table 2-6. Reverse Link Signal Data

Record 1: Receiver Data

Bit Position	No. of Bits	Field Description
1-3	3	Record ID = 001
4-16	13	Time to 60 sec DEL = 0.01 sec
17-21	5	Channel A, B1, B2, B3, C-H (this denotes frequency origin F and step size U. A value of n in the frequency field represents a frequency of (F + n x U.)
22-23	2	Antenna - wide or narrow band or both
24-26	3	Attenuator Setting (0, 3, 6, 10, 15, 20 dB)
27-38	12	Az 0^{o} - 360^{o} DEL = 0.1^{o}
39-49	11	El 0^{o} - 180^{o} DEL = 0.1^{o}
50-66	17	Freq. 0.4 - 40 GHz DEL is variable
67-72	6	Signal Amplitude Field 1 0 - 63 dB DEL = 1 dB
73-78	6	Signal Amplitude Field 2 0 - 63 dB DEL = 1 dB
79-80	2	Polarization (LHCP, RHCP, linear)

Record 2: Shuttle Data

Bit Position	No. of Bits	Field Description
1-3	3	Record ID = 010
4-15	12	Roll in deg DEL = 0.1
16-27	12	Pitch in deg DEL = 0.1
28-39	12	Yaw in deg DEL = 0.1

Record 3: Time

Bit Position	No. of Bits	Field Description
1-3	3	Record ID = 011
4-7	4	Year 0-9
8-16	9	Day 1-366
17-22	6	Hour 0-23
23-28	6	Minute 0-59

Table 2-7. Computation of Frequency Field Size

Band	F (GHz)	BW (GHz)	U	BW/U (K-Steps)
A*	0.4	0.1	0.001	100
B1	1.0	0.5	0.02	25
B2	1.5	0.5	0.2	2
B3	2.0	2.0	1.0	2
C	4.0	4.0	0.2	20
D	8.0	4.0	0.2	20
E	12.0	6.0	1.0	6
F	18.0	8.0	1.0	8
G	26.0	8.0	1.0	8
H	34.0	6.0	1.0	6

*The worst case is band A with 100,000 steps for which 17 bits are needed.

Ground processing is user-oriented. It is designed to provide non-real time displays of graphs, maps and documents. The computer programs for extractive processing are designed to be highly flexible and usable in a wide variety of sequences. A variety of input and output (I/O) devices are selectable for each program. In particular, areas of maps can be selected for blow-up and more detail in an interactive fashion from a CRT. General Electric's Image-System 100, currently being used by Landsat is one way to implement this feature.

The system will provide two types of maps. For any set of parameter requirements - frequency, power, etc. - either a map of interference sources or one of interference levels and directions can be obtained for a specified area. Concomitant information, such as emitter frequencies and polarizations will also be included. The level of geographic detail (e.g., national boundaries) and the projection type (e.g., Mercator) is also selectable. The digitized geographic information is already available and is being used in the Nimbus program. All this can be done interactively, with hard copy generated as needed.

The main system load will be preprocessing and the generating of standard reports and maps. Hence, standard maps will be kept on file in digitized form (File MAF). These maps will be generated from a general geographic file, File GF, whose information is stored in grids, or Marsden squares. There are four basic preprocessing files. File PF contains the estimated emitter location for each data point. The location is found assuming all emitters are on the surface of the earth. The independent data points are grouped together and reformatted to develop a file of independent sources, File SF. File SF takes two forms. File FSF contains all emitter sources found over a given time period. It is mission-oriented. In order to facilitate the collating of large volumes of data over long time periods, specific parameter ranges (location, frequency, etc.) can be pulled from one or more volumes (physical storage devices) of File FSF and re-collated to form a parameter-oriented, or select, file of interference sources, called File SSF. The SF Files are ordered by frequency; each frequency is ordered by emitter location. To permit access of these files using other parameters, a set of three cross-reference files, collectively called the XF File is set up. In order to test the system accuracy and keep track of non-earth-based emitter sources, there is a file of independent information on emitter sources, File EF. There will be a field in the SF File records

to note whether the SF File has been checked against File EF and whether the source really is earth-based.

Information from File SF will be used to determine interference by grids (as in File GF). Frequency, direction, received power level and broadcasting time will be recorded. This information will be ordered by frequency and power within each grid. It will be stored in file IF.

Files SF and IF will be used to generate a file, CF, of specific data for contour maps. The file of interference contours by region regardless of source location is called File ICF. File SCF gives interference contours only for emissions originating in the specified region.

Table 2-8 is a summary of these files. Figure 2-27 is a ground processing flow diagram for EEE. Due to the great flexibility of program concatenation, only a small portion of the non-real time ground processing occurs in a fixed sequence. Only this portion is shown in Figure 2-27. For example, File IF could be generated from File FSF as part of standard preprocessing, or IF Files could be derived from SSF Files, in which case they would represent extractive processing.

Table 2-9 contains a description of the candidate basic computer programs for EEE ground processing. With the above description of the files to be used in ground processing, the table is self-explanatory except for FLAGS and JCOS. FLAGS checks File SF against File EF and notes (flags) the result for each tested emitter source in the SF field provided for that purpose. JCOS is the software for operating the entire EEE ground processing system on a single large computer. There are several kinds of hardware that can be used to implement the EEE ground processing system. The decision to use a large computer, however, cannot be properly determined until trade-off studies have been made.

2.3.6 HARDWARE IMPLEMENTATION

Detailed hardware studies have not yet been undertaken. What follows is a short discussion of the state-of-the-art and the problems involved in the hardware implementation of EEE data processing.

Table 2-8. MMAP/EEE Ground Data Files

- PF = Preprocessing File
  - Equiv. Ground Source Points
  - Contains Computed
    - Signal Direction
    - Effective Isotropic Radiated Power (EIRP)
    - Polarization
    - GMT of Signal
  - Ordered by Freq - LOCN - GMT

- SF = Interference Source File
  - Ground Sources
  - Contains
    - Freq
    - LOCN
    - Power Gain Contour (Points vs. Time)
    - Earth Based Verification Flag
  - Ordered by Freq - LOCN
  - 2 Types
    - FSF - Full SF
    - SSF - Select SF

- XF = Cross-Ref to Freq File
  - LXF = LOCN to Freq
  - PXF = Power to Freq
  - TXF = Time to Freq

- GF = Geographic File by Grid

Table 2-8. MMAP/EEE Ground Data Files (Cont'd)

- IF = Interference File by Grid
  - Contains for each Grid Element
    - Freq
    - Mean Source Direction
    - Mean Power
    - Broadcast Time Slices
  - Ordered by
    - Freq
    - Power

- CF = Contour File
  - 2 Types
    - SCF = Source Contour File
    - ICF = Interference Contour File
  - Contains Reports of
    - Level Curves of Power
    - Freq
    - Source Angle
    - Broadcast Times
  - Used for
    - Regional Maps
    - Reports

- EF = Earth-Based Source File
  - Independent Data on Interference Sources
    - For Checking System, Editing Data
  - Structured like SF

- MAF = Map File
  - Immediately Usable for Display, Paper Maps

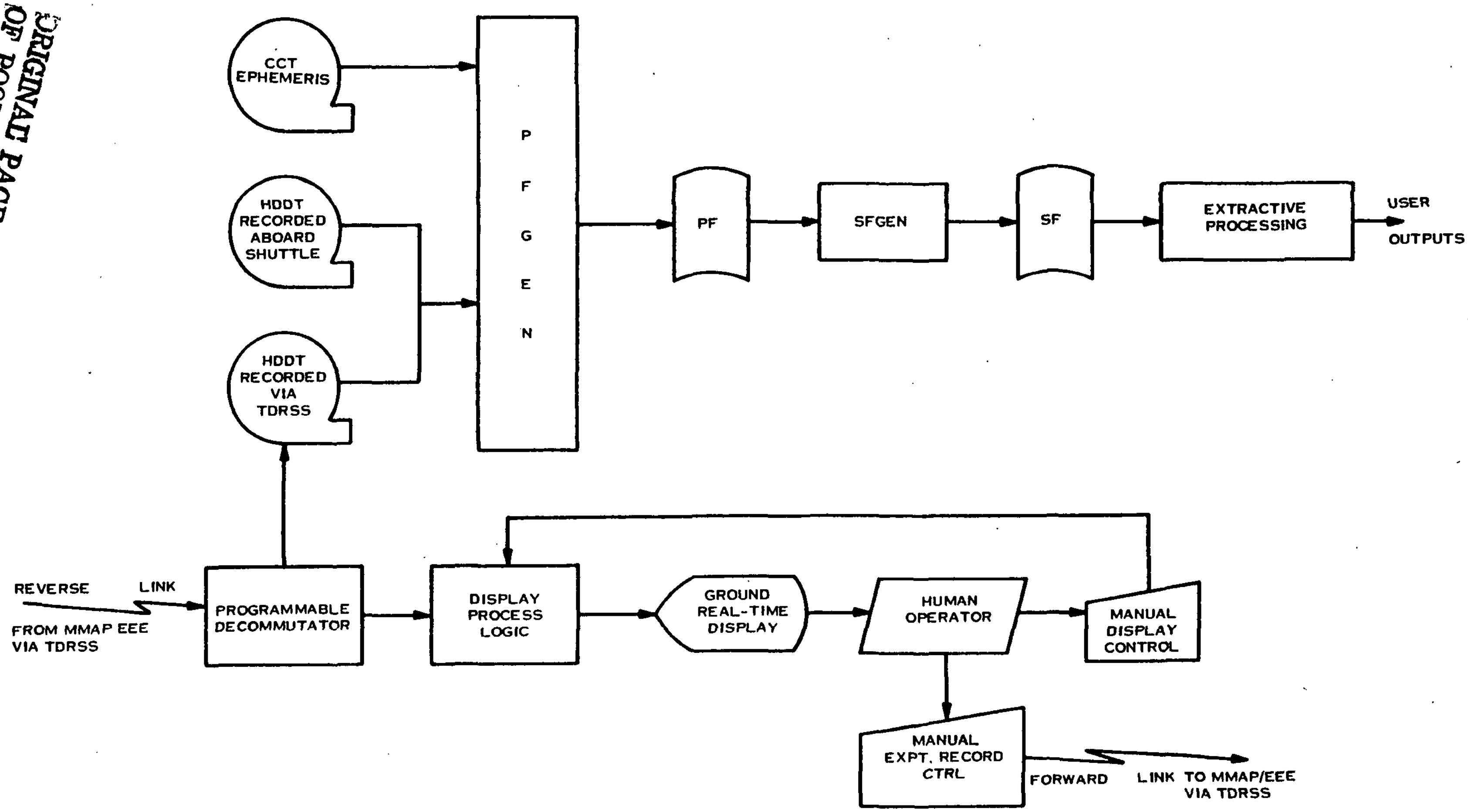

Figure 2-27. MMAP/EEE Ground Processing

Table 2-9. MMAP/EEE Ground Processing Modules

- PFGEN

IP:	Ephemeris on CCT, Data on HDDT
OP:	PF
DESC:	Edit HDDT's Radiometric, Geometric Correction Assume, Locate Earth-Based Sources

- SFGEN

IP:	PF (1 or more)
ØP:	SF, XF Stat. Report of Data Quantity, No. Sources, Etc.
DESC:	Combines Common-Source Data Points Assumes Earth-Based Sources

- SSGEN

IP:	SF, XF (1 or more pairs), Parameter Ranges
ØP:	1 SSF and XF; Stat. Report of ØP

- MAP

IP:	GF; ØP Parameters - Scale, Projection, Bounds, Detail Level, OP Media - Disc, Tape, Paper, Display
ØP:	A Map and Map File (MAF)
Note:	Map Requires no EEE Data

- CMAP

IP:	MAF
ØP:	A Copy of the Map

- IFGEN

IP:	SF, XF, Parameter Ranges
ØP:	IF, Statistical Report

Table 2-9. MMAP/EEE Ground Processing Modules (Cont'd)

- FLAGS

  IP: EF, SF, Parameter Ranges

  ØP: SF with Earth-Based Flag Mods
  Stat. Performance Data
  Discrepancy List

- SCFGEN

  IP: SF, XF, Parameter Ranges, OP Media

  ØP: SCF and Associated Stats.

- ICFGEN

  IP: SF, XF, Parameter Ranges including Altitude, OP Media

  ØP: ICF and Associated Stats.

- CONMAP

  IP: CF, MAF, Region, Parameter Ranges, OP Types and Media

  ØP: Contour Map, Detailed and Stat. Reports

- DCOM

  DESC: Real-Time OCC Display and Expt. CMD and Record
  Ctrl via TDRSS

- JCOS

  DESC: Operating System with

  - Multi-Processing
  - Sophisticated Job Control
  - Real Time
  - Batch
  - Remote

The only practical means for on-board recording of all EEE data for an entire shuttle mission is with a high density digital tape (HDDT). HDDT recording rates are high enough to easily handle the EEE maximum data rate of 2.5 Mbps. The NASA/GSFC shuttle standard tape will have a 1000 to 5000 megabit capacity. The exact capacity has not yet been decided. At the nominal EEE data rate of 83 Kbps, a 1000 megabit tape will hold three hours and 20 minutes worth of data. Hence six of these tapes would be needed for a twenty-hour mission. Due to slewing problems, the tapes would probably be permanently mounted and not interchangeable. Since each drive and tape weighs 250 to 300 pounds, multiple tape drives is not a practical solution. If the 5000 megabit tape were available, a mission of nearly 17 hours could be accommodated on a single drive. This is a reasonable solution. The development of a drive with changeable tapes would also be acceptable. A HDDT with canister weighs about 12.5 pounds.

The HDDT drive is a variable speed device. In order not to waste its capacity, its speed must be dynamically adjusted to accommodate current data rates; but it takes about 30 seconds to get a stationary tape to full speed. Hence, a high speed buffer with a capacity of 15 to 30 seconds of data at maximum rate is needed. This is equivalent to 38 to 75 megabits. Disc systems with the required capacity and speed are currently available off-the-shelf. Whether models suitable for space flight are available remains to be checked. Computer memory is another alternative that appears attractive but has not yet been investigated.

There are a variety of ways to implement ground processing. Table 2-10 indicates one approach. Four other alternatives are shown in Table 2-11.

2.3.7 FUTURE INVESTIGATION NEEDS

Only the broad outlines of the MMAP/EEE data processing configuration have been investigated. The next level of investigation is to more carefully specify the hardware and software system components. Interfaces with other systems must be defined. Future EEE systems analysis can be broken out into six parts:

Table 2-10. An MMAP/EEE Ground Processing Philosophy: The Centralized Processing System

- Large, Fast, Flexible, Reliable Computer
  - HDDT, CCT, Real-Time I/O
  - High Capacity, Fast Peripherals
- Sophisticated OS
  - Multi-Processing
  - Job Control
  - Real Time
  - Batch/Remote
  - Transparent I/O
- Easy-to-Use DBMGT
- Proven Software
- Readily Expandable, Shrinkable
- Reliable and Prompt Hardware, Software Support
- Flexible Throughput, Output
- Modular Applications Software

Table 2-11. Alternate Ground Processing Philosophies for MMAP/EEE

- More DP Aboard Shuttle
  - Costly
  - Less Reliable
- Separate Real Time and Data Crunching Ground Processors
  - Reasonable but chosen Alternative Appears Cheaper
- Parallel Micro/Mini Computers = Distributed System
  - Data Load Appears Heavy for this Approach
  - If Feasible, it is Cost Effective and Reliable
- Hard-Wired Pre-Processor
  - Development Time
  - High Initial Cost
  - Not Flexible

1. On-board processing
2. Communications interface requirements
3. Ground processing
4. A careful study of sensor data volume and rates
5. A specific list of users and their needs
6. Data dissemination requirements

These last two items are often not given the considerable time and effort they deserve. It cannot be over-emphasized that the entire structure and success of the system is critically dependent on this information. For example, only the ultimate users are in a position to determine the timeliness and frequency needs for data.

The types of data processing equipment and hence implementation costs are determined by data volume and rate. More careful study of data loading would be highly cost effective. This involves the whole question of systems integration. EEE is meant to be part of MMAP and final design of the EEE system should dovetail with that of the other component systems. Table 2-12 presents the suggested further study requirements for the MMAP/EEE system implementation.

Table 2-12. MMAP/EEE System Implementation Study Areas

On-Board Processing

- Specification of data formatter
- Processing requirements for EEE computer
  - Command and control types and configurations
  - Speed and capacity requirements
- Hardware trade-off studies
  - Data buffer
  - HDDT device
  - EEE computer
- Interfaces with other equipment
- Hardware, software cost estimates

Communications Requirements

- Availability of TDRSS
- Alternative space-ground links
  - Satellite Tracking and Data Network (STDN)
- Location of ground processing facility
  - Ground link need, availability and capacity

Ground Processing

- Internal file configurations
- Hardware configuration trade-offs
- Hardware and software cost estimates

EEE Integration with MMAP

SECTION 3

SYSTEM DEFINITION

3.1 FREQUENCY PLAN

The primary frequency bands to be covered by the MMAP/EEE are the bands used by NASA for earth to satellite communications and earth observation. These bands have been defined in the frequency range of 0.4 to 40 GHz (Reference 4, 5). However, it is recognized that at frequencies near 22 GHz high propagation attenuation exists due to atmospheric absorption, primarily due to water, affecting earth-to-satellite transmission (Reference 6). The current frequency plan covers the range of 0.4 to 40 GHz, but the 0.4 to 18 GHz region is expected to contain the majority of terrestrial inference emitters.

Search for terrestrial emitters will be conducted in the following frequency bands, either sequentially, or simultaneously:

	Frequency (GHz)	
Band	Frequency Designations	EEE Band
A	0.4 - 1.0	0.4 - 0.5
B	1.0 - 4.0	1.0 - 4.0
C	4.0 - 8.0	4.0 - 8.0
D	8.0 - 12.0	8.0 - 12.0
E	12.0 - 18.0	12.0 - 18.0
F	18.0 - 26.0	18.0 - 26.0
G	26.0 - 34.0	26.0 - 34.0
H	34.0 - 40.0	34.0 - 40.0

Although the EEE will be designed to operate over the frequency bands shown above, only specific bands typically those shown in Table 3-1 are of prime interest. The EEE receiver control computer will be programmed to select only the desired bands, primarily the NASA bands, and to provide receiver blanking of all other bands.

Table 3-1. Typical RF Frequency Bands for MMAP/EEE

Planned Mission Bands	BW	Use
399.9 - 410.0 MHz	10.1 MHz	NASA Space Operation, Data Collection, Radio Astronomy
450.0 - 470.0	20	NASA Meteor. Sat. Data Collection, Land Mobile
1220 - 1280	60	MMAP SSR Experiment
1350 - 1450	100	MMAP SMS R/M Experiment, NASA SEASAT SAR (1330-1350 MHz), Radio Astronomy (H Line) (1400-1427 MHz)
1636.5 - 1670	33.5	Maritime/Aeronautical Mobile Sat., Radio Astronomy OH line
2040 - 2110	70	NASA Earth to Sat. Data/Telecommand/Ranging
2200 - 2300	100	NASA Sat. Data Relay (TDRSS S-Band)
2655 - 2690	35	Fixed Sat. (Earth to Space)
2690 - 2700	10	Intern. Protected exclusive Radio Astronomy
4995 - 5000	5	Radio Astronomy (exclusive)
5725 - 5925	200	Fixed Sat. (earth to space)
5925 - 6425	500	NASA Sat. (earth to space)
6475 - 6725	250	NASA Sat: Nimbus G SMMR
7900 - 7975	75	Fixed Sat. (earth to space)
9950 - 10050	100	MMAP SSR Experiment
10.6 - 10.7 GHz	0.1 GHz	Radio Astronomy (Exclusive)
10.95 - 11.2	0.25	Fixed Sat. (earth to space)
12.5 - 12.75	0.25	Fixed Sat. (earth to space)
13.1 - 15.7	2.6	NASA Fixed Sat. (earth to space) - SEASAT Wind field scatterometer, short pulse altimeter, ATS-6 MMW experiment. TDRSS Ku-Band
17.7 - 24.0	6.3	NASA - ATS-6 MMW experiment, Nimbus - F SCAM radiometer, Nimbus - 5 (ESMR), Nimbus - G SMMR, and Radio Astronomy (H_2O vapor line), MMAP A&O R/M (18 GHz)
27.5 - 35.2	7.7	Fixed Sat., Space Research and Radio Astronomy (31.3 - 31.5 GHz, 33.0 - 33.4 GHz). Nimbus-5 NEMS (31.4 GHz), Nimbus-F SCAM (31.65 GHz), MMAP MMWC (29.7-30.2 GHz)
35.5 - 40	4.5	NASA Sat: Nimbus-F ESMR (37 GHz), Nimbus G SMMR (37 GHz), MMAP A&O R/M (36 GHz)

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3.2 FUNCTIONAL SYSTEM

The MMAP/EEE system involves equipment needed to detect earth based emitters, process and transmit data from the Spacelab to a ground based processing center, and ground equipment to process these data for User information. Figure 3-1 shows the major functions of the system to be implemented for the Electromagnetic Environment Experiment. The functions directly involved are the Upper Antenna Assembly and rotary joint used to provide azimuth-elevation antenna scanning, the Spacelab equipment including on-board data processing, storage and display functions, and the EEE Ground Processing Equipment. Data will be transferred from the Shuttle to the ground equipment via the Shuttle-TDRS-White Sands Ground Station link of the Tracking Data and Relay Satellite System (TDRSS). The system will include means for recording data on-board the Spacelab and controls for operation of the experiment by an on-board specialist.

The Upper Antenna Assembly contains the antennas used to cover the designated frequency bands for EEE, antennas to provide narrowbeam and widebeam coverage, frequency downconverters for each band, local oscillators and antenna control equipment. This assembly will also include additional equipment to interface with other experiments in the MMAP. Figure 3-2 shows a functional block diagram of the assembly and interface points with MMAP. Figures 3-3 and 3-4 show two possible mechanical arrangement of the antennas and some of the associated equipment in each assembly. The main interface between the Upper Antenna Assembly and the Spacelab is the rotary joint and transmission lines and cables that provide connections to the Spacelab. Experiment power and controls are located in the Spacelab, requiring prime power, control signal and IF interconnections through the rotary joint and/or slip rings.

Spacelab equipment includes the experiment control equipment, data processing equipment, display/operator equipment, data storage equipment and Spacelab communications interface equipment. This Spacelab equipment will be rack mounted with a control/display console. Standard on-board Spacelab equipment will be used if available, and data transfer will be accomplished through the Shuttle communication links using the S-band and/or Ku-band systems.

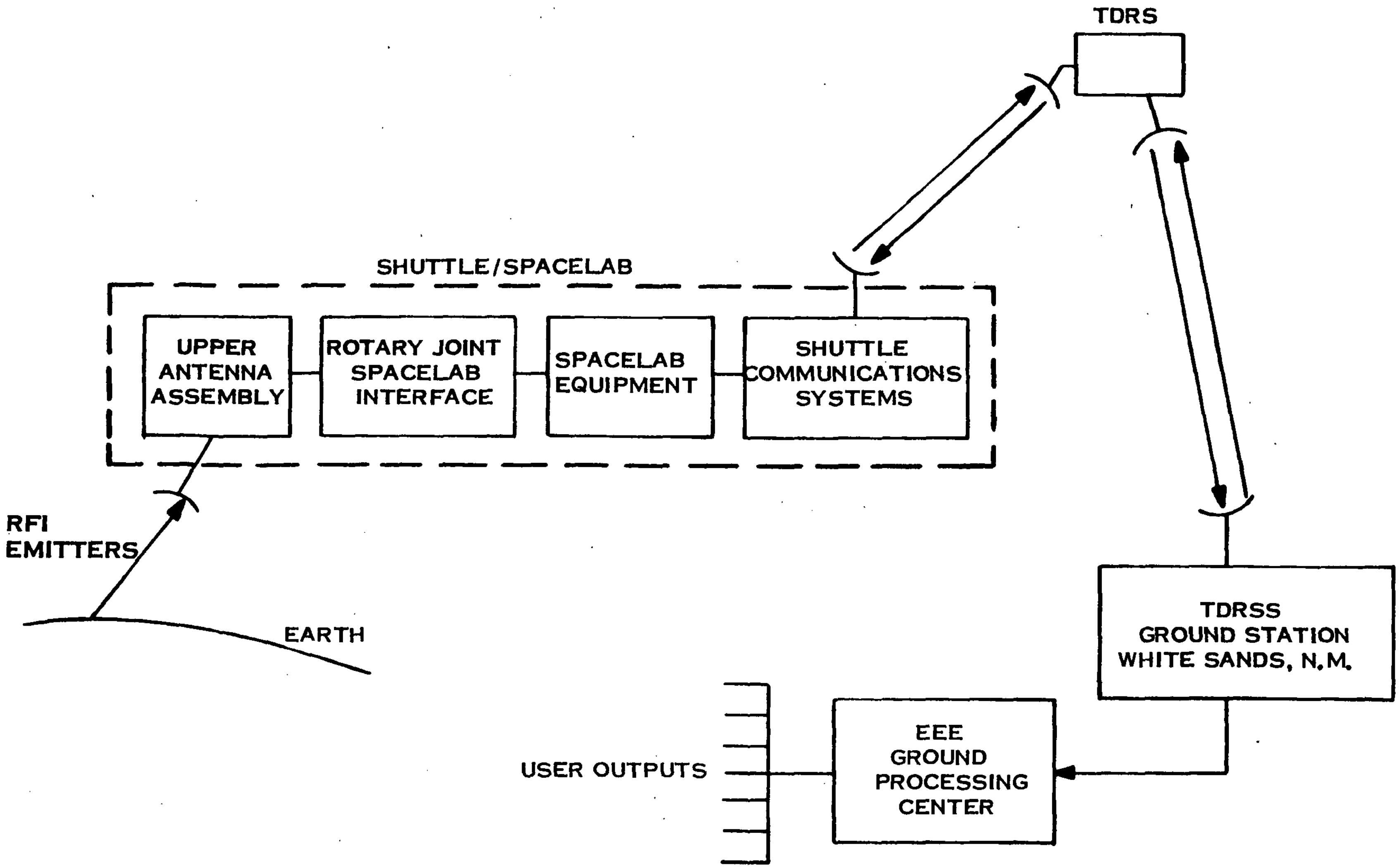

Figure 3-1. MMAP/EEE Functional System

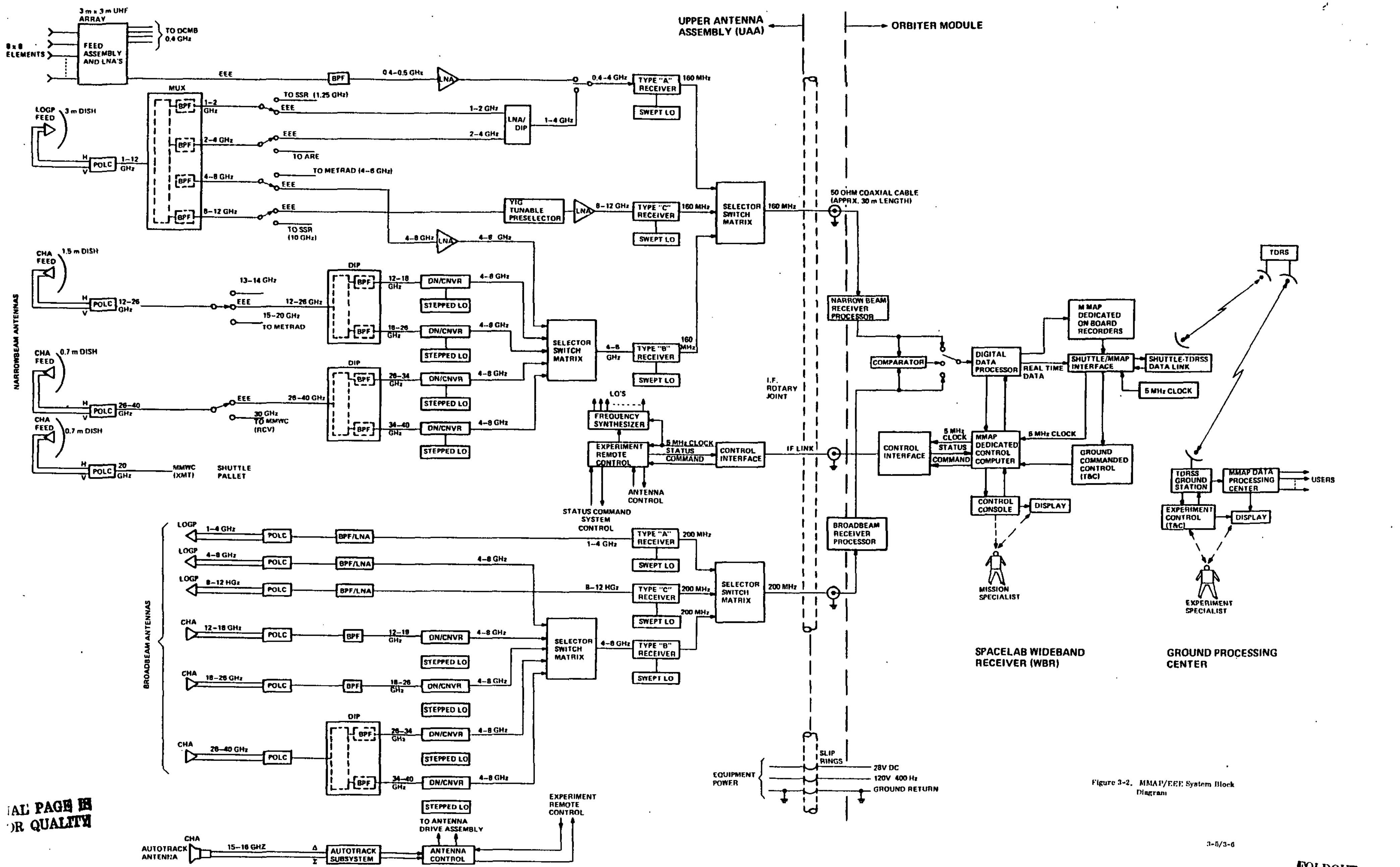

Figure 3-2. MMAP/EEE System Block Diagram

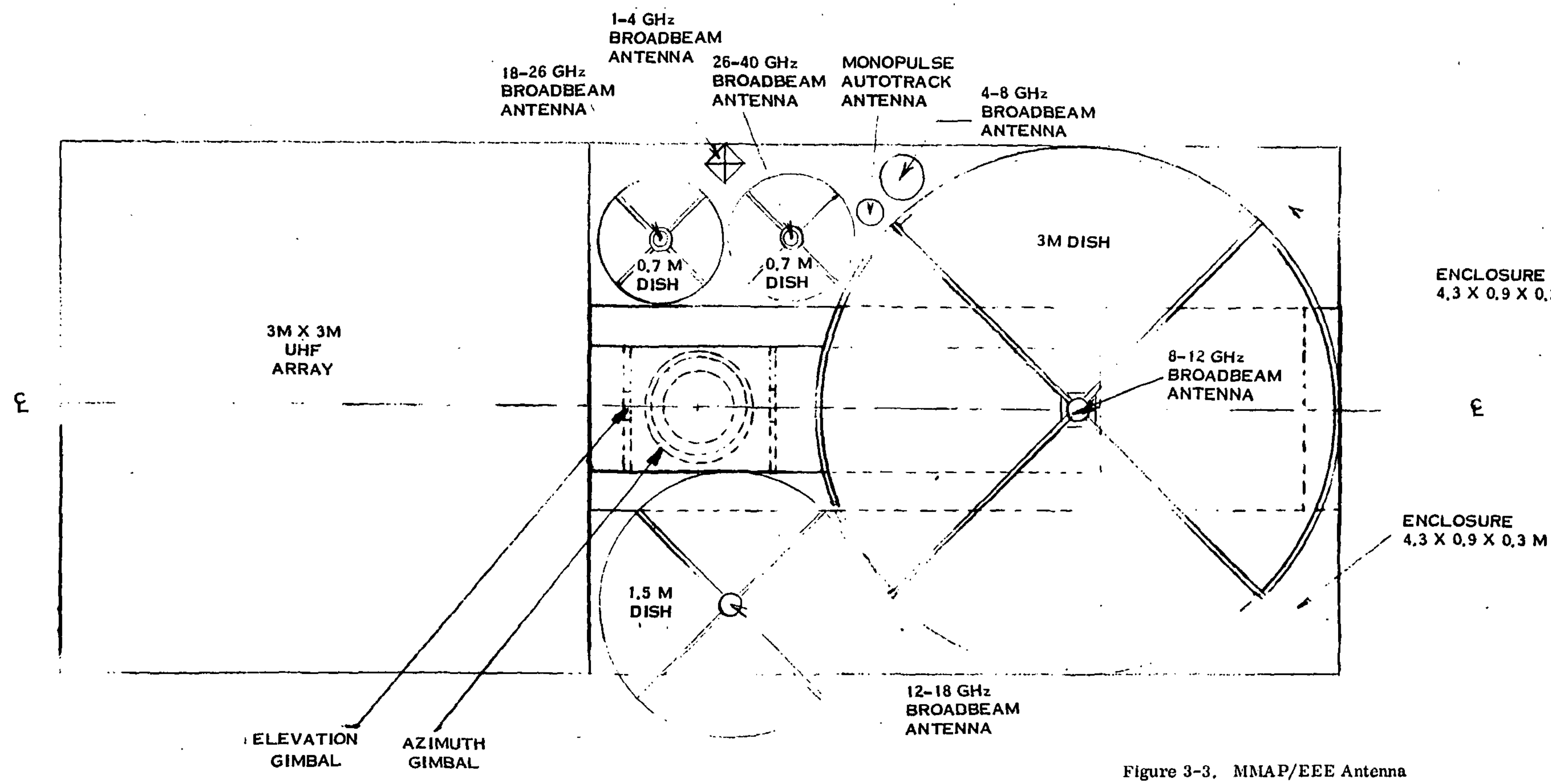

Figure 3-3. MMAP/EEE Antenna Configuration

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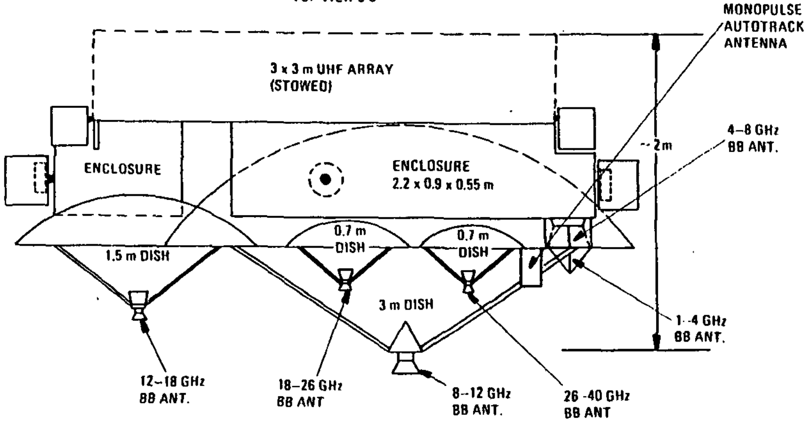
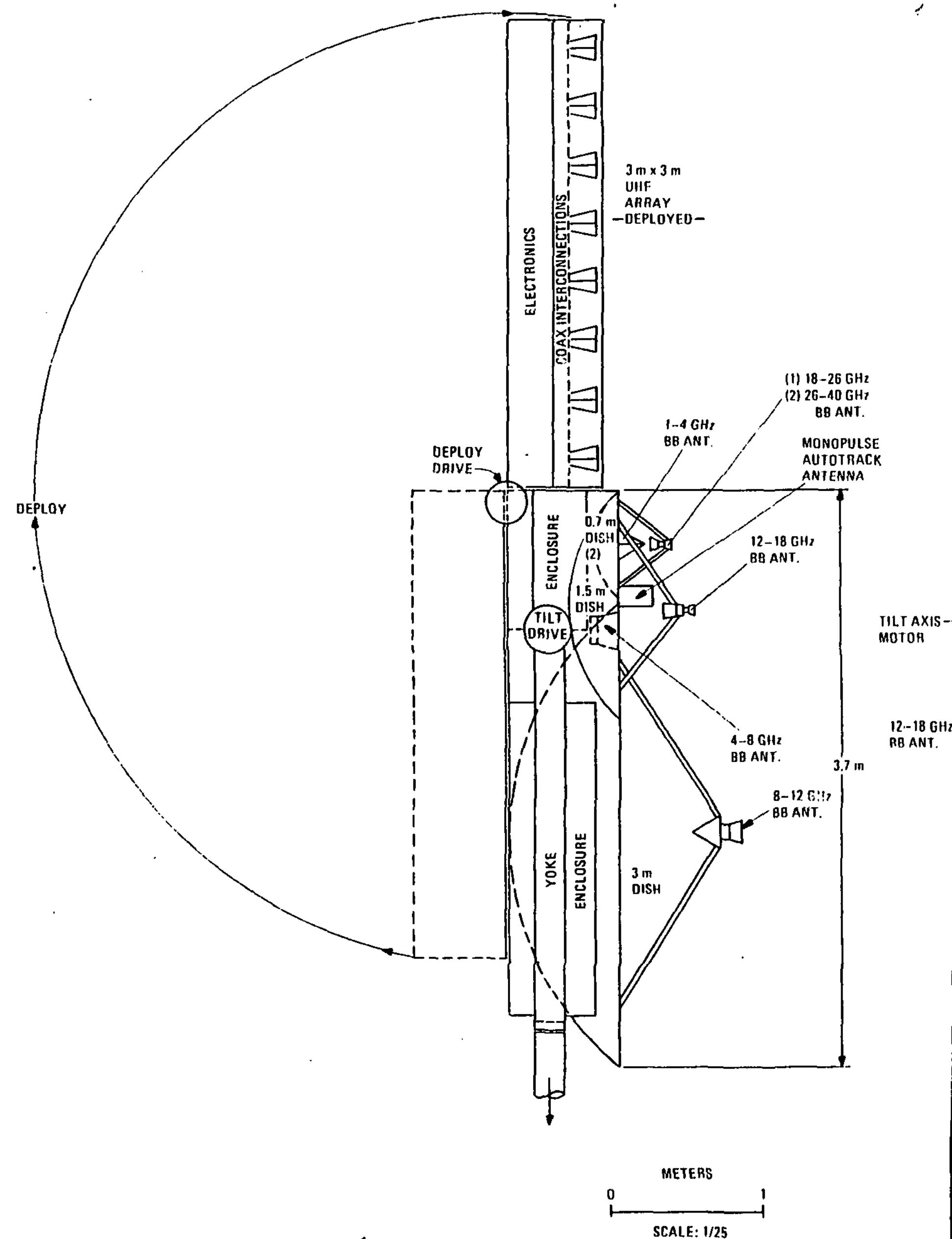
FOLDOUT FRAME 2

NOTE: ABBREVIATION "BB ANT." = BROADBEAM ANTENNA

TOP VIEW C-C





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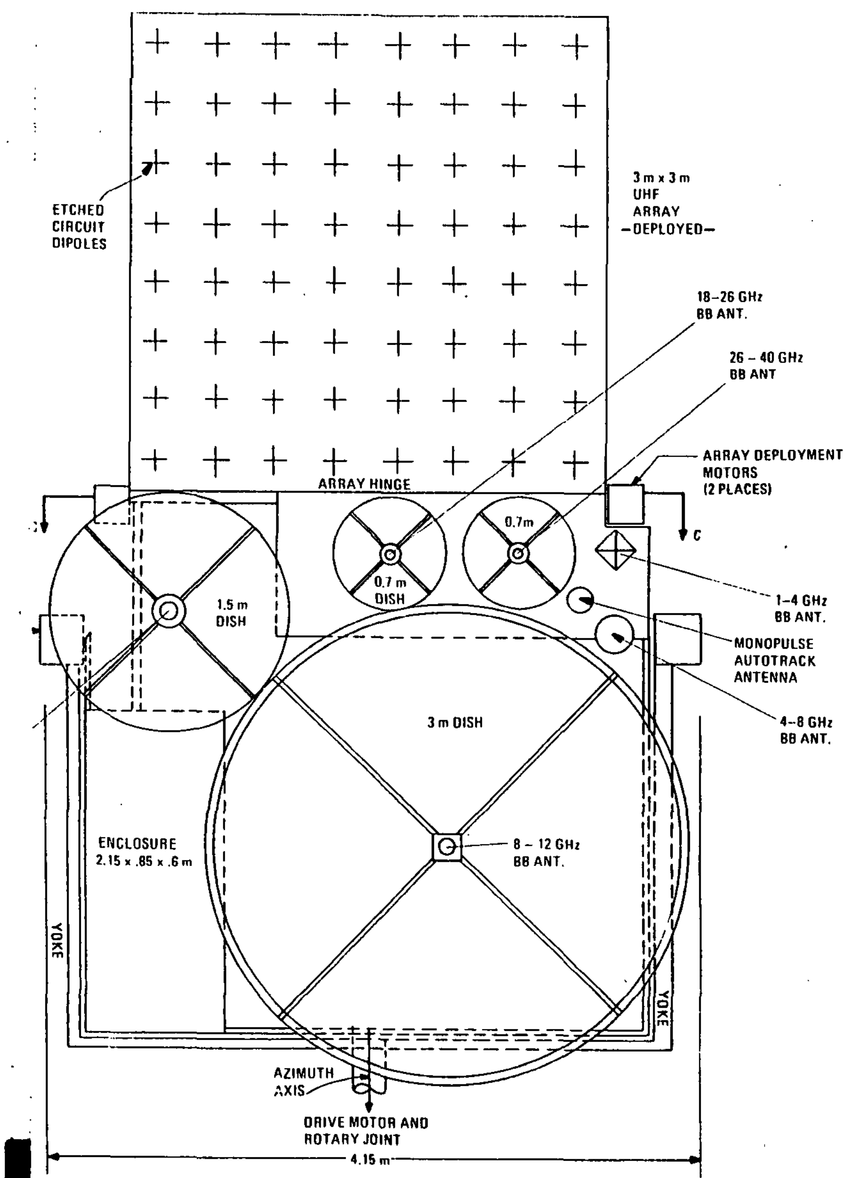

Figure 3-4. Alternate MMAP/EEE Antenna Configuration

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Transfer of data from the White Sands, N.M. TDRSS ground station to the EEE ground processing center will be via a land line microwave relay link or magnetic tape at a maximum data rate of 1.0 Mbps. Data reduction at the EEE ground processing station will include raw data storage, and retrieval by parameter index, e.g., frequency, location, time, power level. Outputs from the processing center could be hard-copy tabulation, graphs and other formats, and/or video displays.

3.3 ANTENNA SUBSYSTEM

3.3.1 UPPER ANTENNA ASSEMBLY

The MMAP/EEE upper antenna assembly provides a radiation measuring capability covering the frequency range of 0.4 to 40 GHz in 8 bands. In addition, each antenna is required to interface and function with other specified MMAP equipment. The MMAP/EEE antenna assembly consists of twelve antennas: a 3m x 3m array covering 0.4 to 0.5 GHz, four narrow beam parabola reflectors and six broadbeam antennas covering 1.0 to 40 GHz, and a Ku-band monopulse tracking antenna. The general relationship of the antenna to the MMAP experiments is shown in Appendix A. Performance parameters for the antennas are listed in Table 3-2. Two typical mechanical assemblies are shown in Figures 3-3 and 3-4.

The antennas of Table 3-2 are mounted on a common base that is azimuth scanned and elevation tilted as required for the various MMAP/EEE experiments. Scanning and pointing are controlled from the control console in the Shuttle; monopulse tracking is accomplished by the Ku-band tracker mounted on the assembly. The boresights of all antennas on the mount are parallel.

The configurations shown in Figures 3-3 and 3-4 show the feasibility of locating the entire group of antennas on a single mount of a nominal size capable of being stowed in the Shuttle bay. The 3m x 3m array, stowed behind the group of reflectors, can be hinged from the side or top, assuming sufficient space and mounting arrangements can be realized. The 3m and 1.5m dish antennas establish minimum overall

Table 3-2. MMAP/EEE Antenna Summary†

	MMAP/EEE Antennas†											
Frequency - GHz	0.4-0.5	1-12	1-4	4-8	8-12	12-26	12-18	18-26	26-40	20	26-40	15-16
Antenna Type	3 x 3m Planar Array	3m Dish	LOGP	LOGP	LOGP	1.5m DISH	CHA	CHA	0.7m DISH (#1)	0.7 DISH (#2)	CHA	0.15m Dia. CHA
Beamwidth - Degrees	15-12	7.0-0.6	70	30	30	1.1-0.5	30	30	1.3-0.9	1.3	30	30
Gain (dB)	20-22	25-44	7.5	TBD	TBD	42-52	TBD	TBD	42-46	40	TBD	15
Feed Type	(NA)	LOGP	(NA)	(NA)	(NA)	CHA	(NA)	(NA)	CHA	CHA	(NA)	(NA)
Autotrack Angular Accuracy	-	-	-	-	-	-	-	-	-	-	-	$\pm 0.1^{o}$
Polarization	RHCP	RHCP/ LIN	RHCP/ LIN	RHCP/ LIN	RHCP/ LIN	RHCP/ LIN	RHCP/ LIN	RHCP/ LIN	[1]RHCP/ LIN [2]Simultaneous RHCP/ LHCP	Simultaneous RHCP/ LHCP	RHCP/ LIN	RHCP
Steering	Mechanical											
Scan Coverage - Azimuth	360^{o}											
- Elevation (tilt)	Nadir $\pm 80^{o}$											
Scan Rates - Azimuth	$0\text{-}50^{o}$ Per Second											
- Elevation	TBD											
Scan Accelerations	TBD											
MMAP Users	EEE DCMB	EEE SSR ARE METRAD	EEE	EEE	EEE	EEE ARE METRAD	EEE	EEE	[1]EEE [2]MMWC	MMWC XMT	EEE	ARE MMWC

†REF. 8 Data on this chart were supplied by S. Hamren, Hughes Aircraft Co., Culver City, Ca.

Legend:
LOGP = Log Periodic
CHA = Corregated Horn Antenna
RHCP = Right Hand Circular Polarization
LIN = Linear
LHCP = Left Hand Circular Polarization

dimensions for the assembly; all other antennas will fit within the area shown. Typical enclosures for the electronic gear are indicated, but additional space is available if required. The final configuration will incorporate the physical characteristics of the components into an arrangement to optimize both the mechanical and electrical performance commensurate with space restrictions in the Shuttle bay volume, and scanning and pointing functions.

The antenna assembly will include a multi-channel rotary joint for IF frequency channels, and slip rings to provide prime power and low frequency controls to the antenna mount. The drive motors on the assembly must provide the scan/tilt performance of Table 3-2.

Figure 3-5 is an overall block diagram of the antenna configuration, showing the antennas, feeds, polarization controls, and feed-line switches. Diplexers, bandpass filters, and other components are discussed with the receivers in Section 3.4.

3.3.2 MMAP/EEE 3m x 3m UHF ARRAY ANTENNA

The 3m x 3m UHF array uses 64 elements (8x8 array), equally spaced, that simultaneously covers the 0.4 to 0.5 GHz range for the EEE and provides 4 fixed beams for the DCMB Experiment of MMAP. The DCMB uses only two of the eight rows of array elements.

In the EEE mode, the antenna operates as a broadside planar array with all 64 elements in-phase. The feed assembly is of a corporate type that includes LNA's to offset power-division losses. A single coaxial line from the antenna feed assembly connects to the EEE receiver through a band-pass filter, attenuator, and limiter. All electronics inputs up to the point of the IF rotary joint are located in the back of the array. The characteristics of the array as related to EEE requirements are given in Table 3-3.

The 3m x 3m UHF array can be stowed at the back of the assembly of reflector antennas as shown in Figures 3-3 or 3-4. In both arrangements the array must be deployed, and

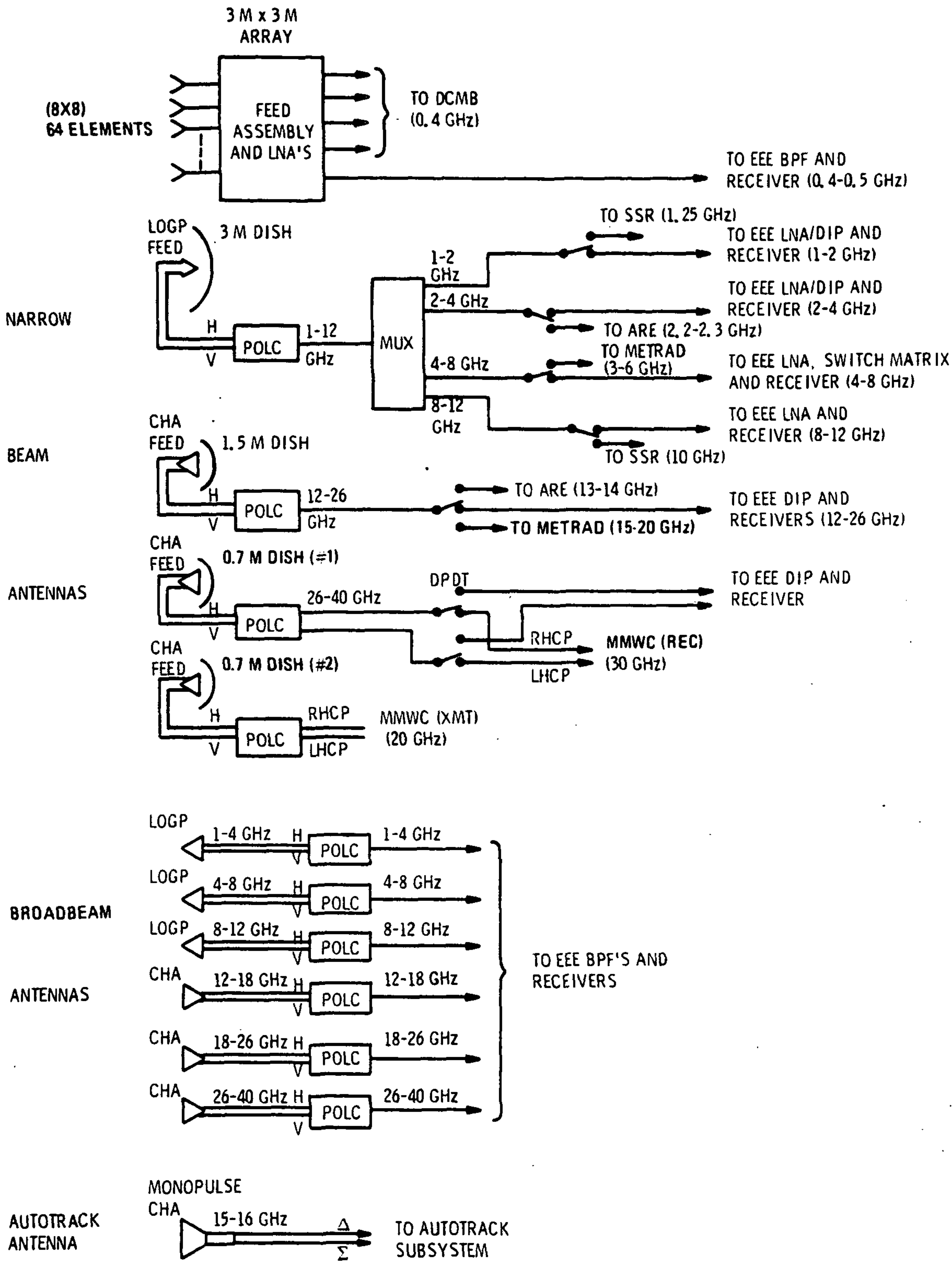

Figure 3-5. MMAP/EEE Antenna Subsystem

Table 3-3. MMAP/EEE 3m x 3m UHF Array[†]

Frequency	0.4 - 0.5 GHz
Type	Planar Array
Dimensions	3m x 3m
Gain	20 - 22
Elements	8 x 8 equally spaced, Conical Spiral radiators
Polarization	RHCP
Beamwidth (3 dB)	15° to 12° over band
Sidelobes	-20 dB
Output VSWR	<1.5:1
Weight	100 kg
Feed Loss	2.85dB
Supplementary Requirements for DCMB Function	
Frequency Range	0.4 - 0.41 GHz
Elements	One Group: 2 elements high, 8 elements wide
Feeds	Spiral
Polarization	RHCP
Beamwidths (3 dB)	15° x 60°
Gain	14 dB per beam
Outputs	4 terminals
Output VSWR	<1.5:1
Scan Pattern	Fixed forward looking; beams squinted TBD° either side of track in azimuth

[†]REF. 8

the assembly must include flexible cables to interconnect the array with the main antenna structure electronic equipment. Deployment motors are required, and motor power must be sufficient to operate the array deployment in a one "g" environment with test counterweights.

Since the same array is used for the MMAP/DCMB mode, the corporate feed structure employs phase shifters which generate four separate beams from a single set of elements; the elements to be used are the third and fourth rows, for a total of eight elements in azimuth and two in elevation. Four banks of phase shifters provide four beams, each 15^{o} in azimuth by 60^{o} in elevation. The beams are separated in azimuth by TBD^{o} between boresights. The normal operating mode for the DCMB will be a forward-looking antenna position. Eight 7-dB gain LNA's used in the array will be sized to permit the signals of the eight 2-element columns to be split five ways for generating the four separate DCMB beams, and to provide a signal for the EEE. The outputs of the four DCMB beams will be provided at four terminals, where each corrects to a BPF and receiver channel.

Figure 3-6 indicates the basic EEE/DCMB interfacing for the 3 x 3m UHF array.

3.3.3 MMAP/EEE 3 METER REFLECTOR ANTENNA

A 3 meter diameter, metallic reflector antenna with a log periodic feed is used to cover the frequency range from 1 to 12 GHz. The required characteristics of the antenna are indicated in Table 3-4. The feed is required to provide selectable polarizations via a switch in the feed-line. Other switches in the feed line permit the receiver covering the 1 to 12 GHz frequency range to switch between the EEE and other MMAP experiments. The antenna assembly will include an RF output switch to provide for operation with either EEE or ARE experiments as noted in Figure 3-7.

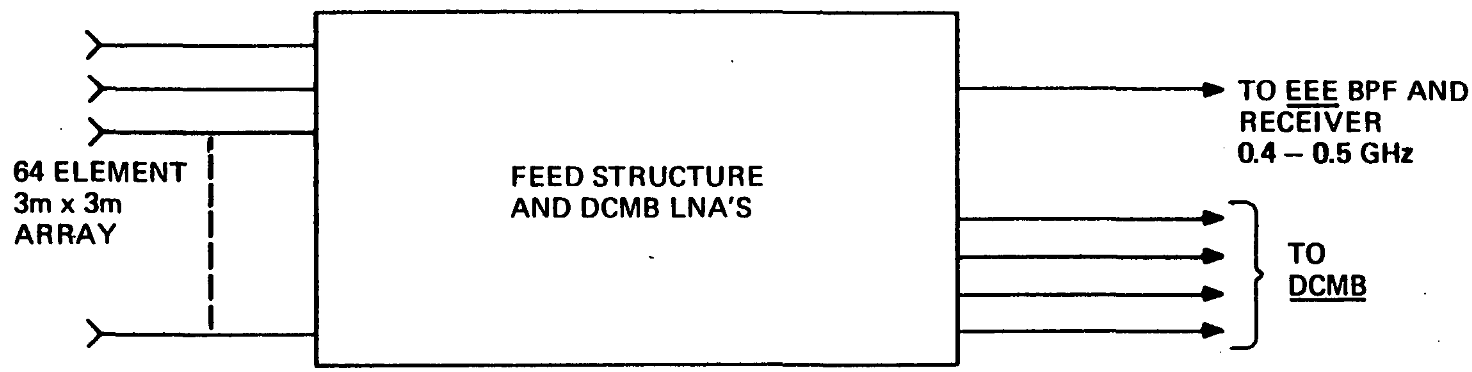

Figure 3-6. 3m x 3m MMAP EEE and DCMB Experiments UHF Array Antenna

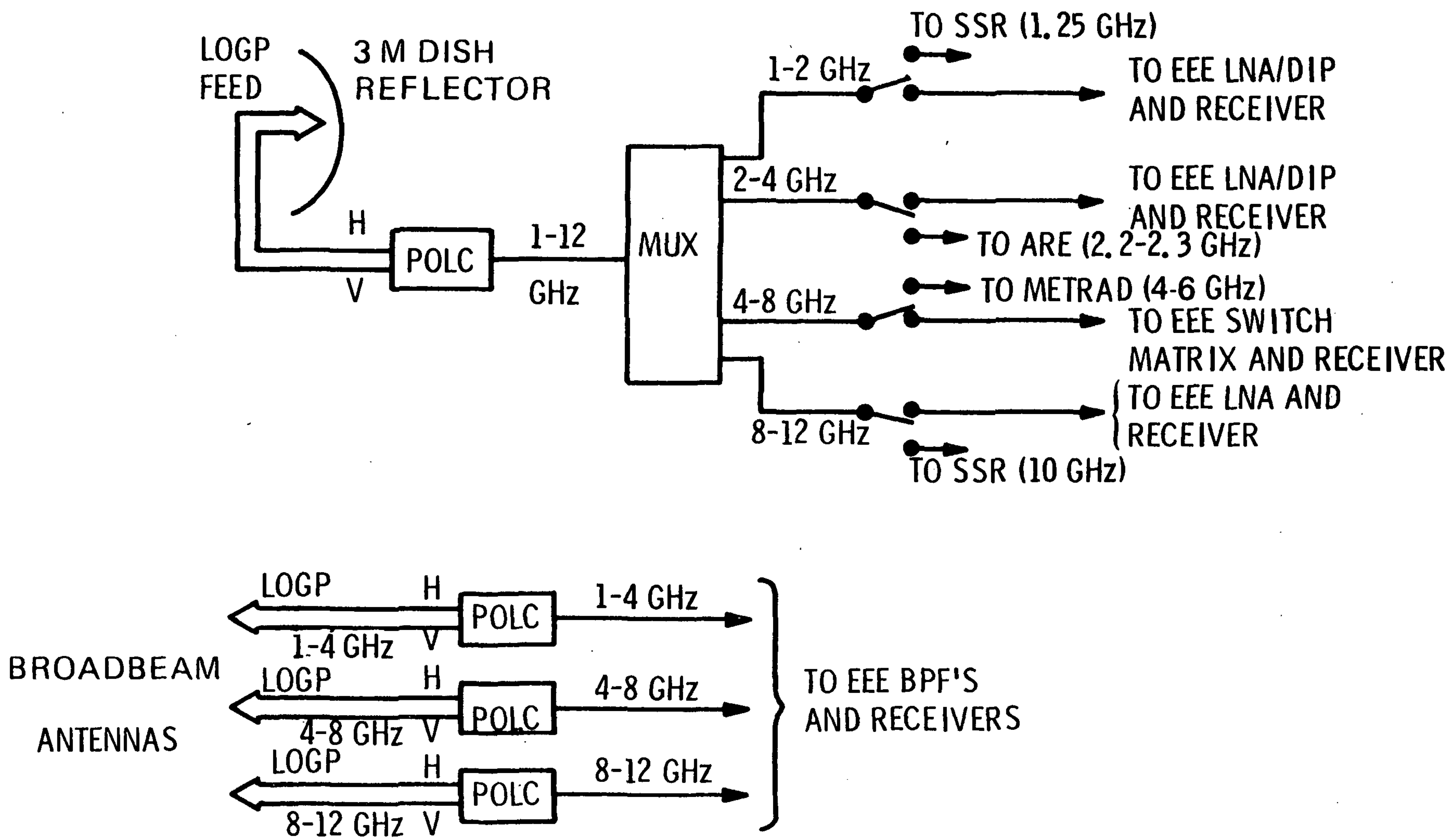

Figure 3-7. 3m Diameter MMAP/UAA Reflector

Table 3-4. MMAP/UAA 3m Diameter Reflector[†]

Frequency Band - GHz	1.0 - 4.0	4.0 - 8.0	8.0 - 12.0
Gain Range - dB	25 - 36	36 - 42	42 - 44
3 dB Beamwidth - Degrees	7 - 1.7	1.7 - 0.9	0.9 - 0.6
Feed Type	Log Periodic →		
Polarization	Selectable RHCP or Linear		
Sidelobes - dB Down	-19 min.	-22 min.	-19 min.
Input Component Loss (dB)	TBD	TBD	TBD
Function Select Switch*	Four SPDT switches following Multiplexer		
Output VSWR, EEE Terminal	(2.5-3.0):1	2.0:1	(2.5-3.0):1

*Required for other MMAP equipments: ARE, METRAD SSR
†REF. 8

3.3.4 MMAP/UAA 1.5 METER REFLECTOR

The 1.5 meter diameter metallic reflector antenna uses a corrugated horn feed to cover the frequency range of 12 to 26 GHz. The required antenna characteristics are included in Table 3-5. The horn feed is required to provide selectable polarizations via a switch in the feed line. The output of the RF assembly includes an RF switch which connects the antenna to either the EEE, METRAD or ARE equipment. Figure 3-8 shows the antenna feed and switching networks; Table 3-5 details the performance characteristics.

C.2

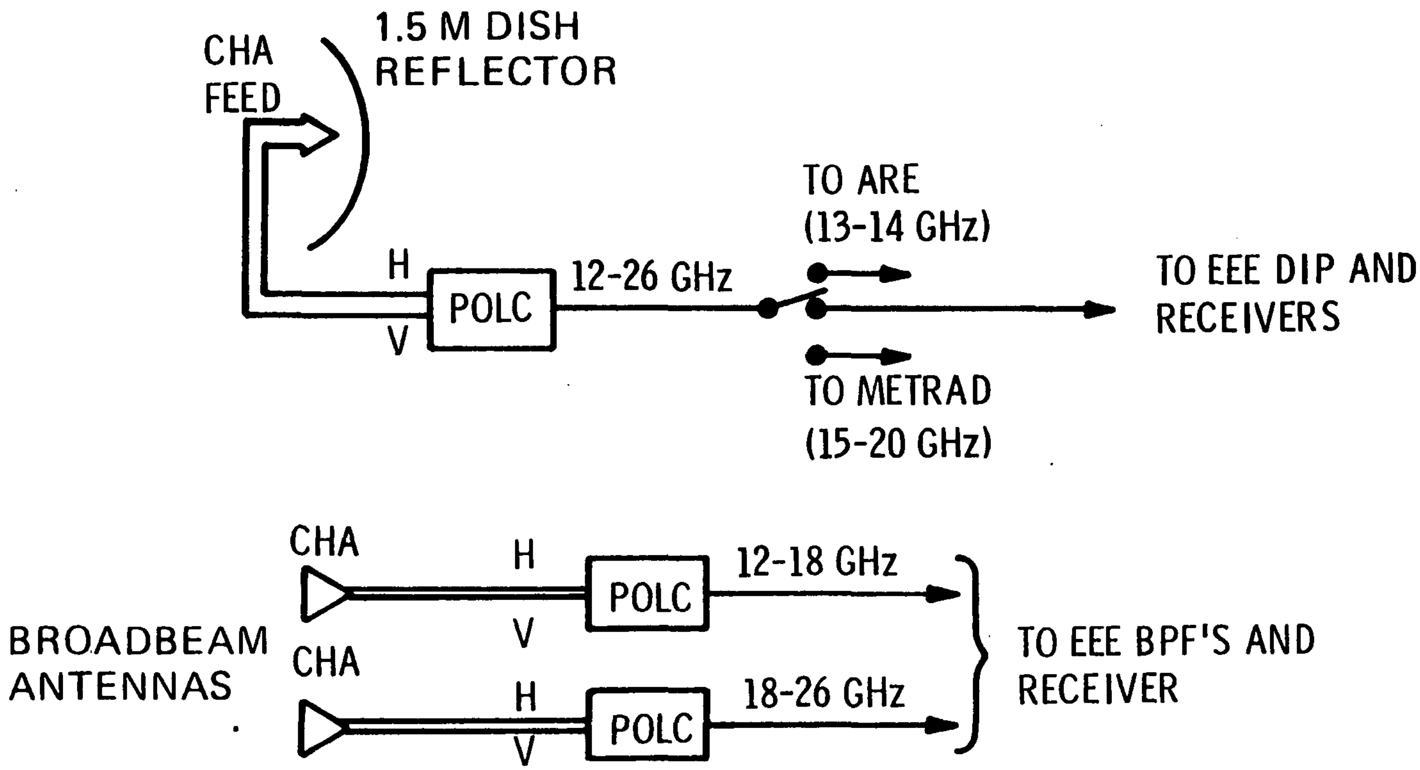

Figure 3-8. 1.5 Meter Diameter MMAP/UAA Reflector

Table 3-5. MMAP/UAA 1.5M Diameter Reflector†

Frequency Band - GHz	12 - 18	18 - 26
Gain Range - dB	40 - 43	43 - 47
Beamwidth Range - degrees	1.1 - 0.8	0.8 - 0.5
Feed	Corrugated Horn →	
Polarization	RHCP/LINEAR	
Sidelobes - dB Down	-22 min.	-22 min.
Input Component Loss - dB	TBD	TBD
Function Switches	SP3T* →	

*Required for other MMAP Equipments; ARE, METRAD
†REF. 8

3.3.5 MMAP/UAA 0.7 METER REFLECTORS

Two 0.7 meter diameter reflector antennas are included in the upper antenna assembly (UAA). The first is used for EEE and MMAP/MMWC receive functions; the second is used only for the MMWC transmit function. The general characteristics of the two antennas are included in Table 3-6. A diagram of the 0.7m antenna configuration is shown in Figure 3-9; the separate 0.7m antennas are used to provide optimized coverage for the 26-40 GHz EEE receiver and to isolate the 20 GHz transmitter from the MMWC receiver.

The RF feed for the EEE receive antenna provides RHCP or one linear polarization, and the Polarization Control device simultaneously forms both RHCP and LHCP for the MMAP/MMWC equipment. The two polarizations are selectable as required for the EEE mode. An output RF switch selects the EEE or MMWC receivers.

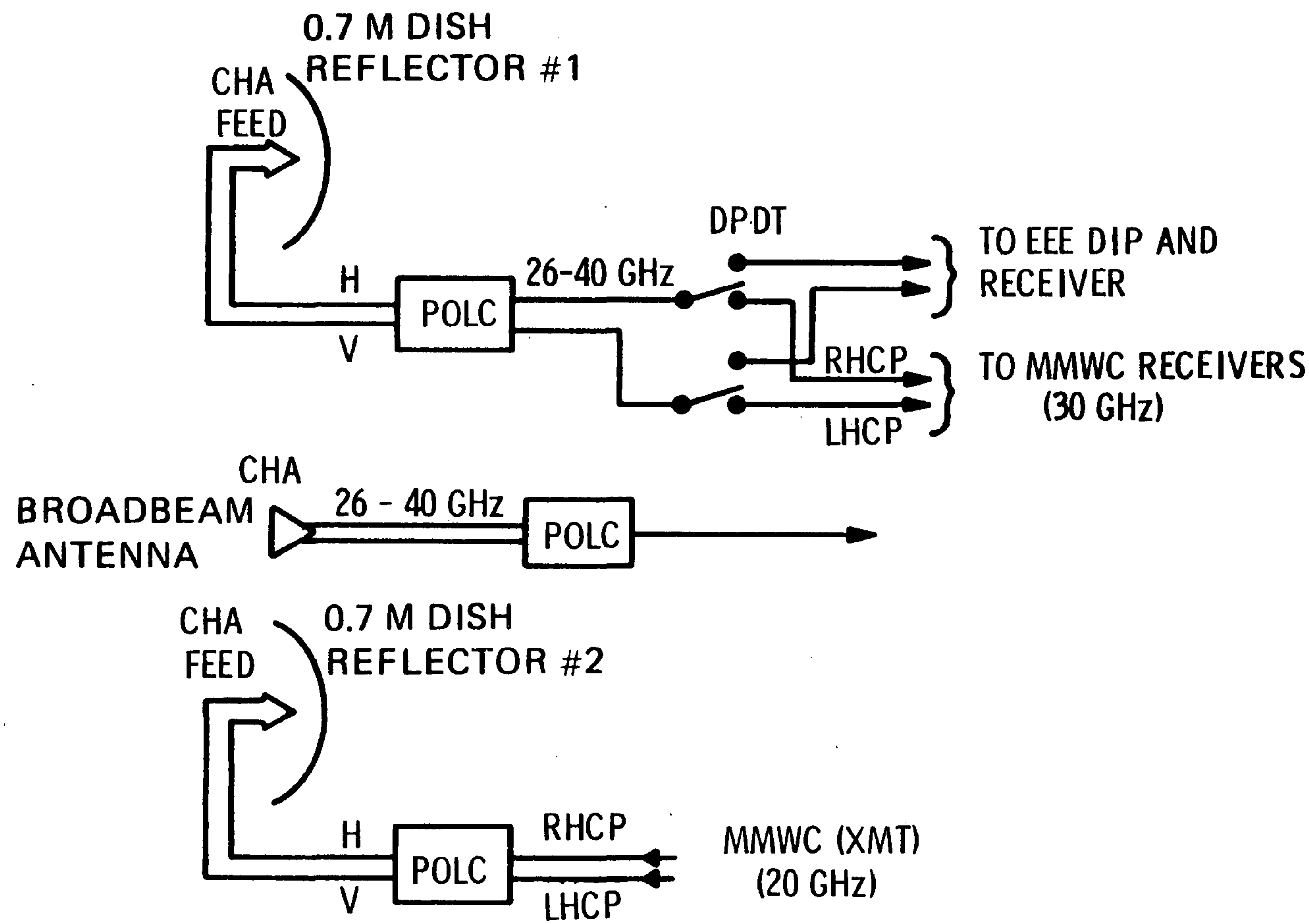

Figure 3-9. 0.7 Meter Diameter MMAP/UAA Reflectors

Table 3-6. MMAP/UAA 0.7M Diameter Reflector†

	#1 Antenna	#2 Antenna
Frequency Band - GHz	26 - 40	20
Gain Range - dB	40 - 44	40
Beamwidth - degrees	1.3 - 0.94	1.3
Antenna Type	Reflector →	→
Feed	Corrugated Horn →	→
Polarization	RHCP/Linear → and Simultaneous RHCP and LHCP →	→
Sidelobes (dB below main beam)	-15 min.	-15 min.
Input Component Loss (dB)	TBD	TBD
Antenna Selector Switch	SPDT →	NA

†REF. 8

3.3.6 MMAP/UAA BROADBEAM ANTENNAS

The three EEE reflector antennas described above have associated broadbeam antennas that have the characteristics listed in Table 3-7. The frequency bands are different from the reflector antennas but cover the same overall frequency range. The 3 dB beamwidth is 70° for the 1-4 GHz antenna and approximately 30° for the other five broadbeam antennas.

3.3.7 MMAP MONOPULSE ANTENNA

A monopulse tracking antenna assembly is included in the MMAP to provide autotrack for the MMWC and ARE experiments. Characteristics for an ARE and MMWC monopulse tracking antenna are included in Table 3-8. The operation of this antenna can be integrated with some of the EEE equipment and, in particular, provide the steering controls used with the MMWC and ARE experiments. Operation will be nominally in the Ku-band region, between 15 and 16 GHz.

Table 3-7. MMAP/UAA Broadbeam Antennas[†]

Frequency Range - GHz	1 - 4	4 - 8	8 - 12	12 - 18	18 - 26	26 - 40
Associated Antenna	3m DISH	3m DISH	3m DISH	1.5m DISH	1.5m DISH	0.7m DISH
Antenna Type	LOGP	LOGP	LOGP	CHA	CHA	CHA
3 dB Beamwidth - Degrees	70	30	30	30	30	30
Gain - dB	7.5	TBD	TBD	TBD	TBD	TBD
Polarization	← RHCP/Linear →					
Sidelobes - dB	TBD	TBD	TBD	TBD	TBD	TBD
Input Component Loss (dB) -Estimated	TBD	TBD	TBD	TBD	TBD	TBD

[†]REF. 8

Table 3-8. MMAP Ku-Band Broadbeam Monopulse Tracking Antenna

Frequency (GHz)	15 - 16
Antenna Type	4-probe corrugated horn
3 dB Beamwidth (Sum channel)	30°
Diameter	0.15 meter
Angular Tracking Accuracy	$\pm 0.1^{\circ}$ or better
Gain	TBD
Polarization	RHCP
Null Depth	$<$ 30 dB below Σ peak

3.4 RECEIVER SUBSYSTEM

The MMAP/EEE Receiver Subsystem is composed of the diplexers, downconverters, detectors, and data processing equipment for the frequency bands defined in Section 3.1. Receiver performance is determined by noise figure, dynamic range, frequency measurement range, EIRP measurement, polarization detection, signal processing for data display, and other related system operational factors such as interface controls between other MMAP experiments and Shuttle/Spacelab. The receiver is composed of eight pairs of sub-receivers as shown in Table 3-9 that use both narrowbeam and broadbeam antennas for the specified frequency bands. Each sub-receiver is controlled independently and can operate as a single unit or simultaneously with the comparison narrow and broadbeam antennas. Data output from each receiver will be processed separately, but can be compared with data from its companion receiver for dual beam operation. System controls operated by the receiver computer or manual operation, include frequency band selection, frequency scan control, antenna scan, receiver blanking, receiver sensitivity and display controls. Data processing and interface controls will be integrated with the receiver computer and the overall Shuttle experiment control computers.

Key interfaces for the receiver are the antenna output, the rotary joint, the data storage equipment, the Shuttle data transmission equipment, experiment controls and display equipment. Figure 3-2 shows the receiver functions and interface points with the antenna and data distribution system. Included in the receiver subsystem are the frequency synthesizer which controls all LO's, receiver sensitivity control and protection, and multiplexing and de-multiplexing of IF signals for transmission through the rotary joint.

Although the receiver is designed to operate over the entire band of 0.4 - 40 GHz, only specific frequency bands are of prime interest to NASA. These bands are listed in Table 3-1. The receiver control computer will be programmed to provide local oscillator power only for the specific NASA bands and to provide receiver blanking to avoid detection of signals outside the designated bands. Similarly, signal detection level and sensitivity controls will be provided to prevent receiver saturation and allow large signals to be evaluated.

Table 3-9. Receiver Electrical Performance Specifications

Performance Parameter	Frequency Band A	B	C	D	E	F	G	H
Frequency (GHz)	.4 - .5	1 - 4	4 - 8	8 - 12	12 - 18	18 - 26	26 - 34	34 - 40
Resolution Bandwidth (MHz)*	.001							
(Selectable	.02	.02	.20	.20	1.0	1.0	1.0	1.0
	.2	.2	1.0	1.0	10.0	10.0	10.0	10.0
		1.0						
Frequency Sweep Time (Sec)								
Resolution BW								
.02 MHz	.375	.3 **						
.2	.375	.25**						
1.0		.4 **	.4	.4	.6	.4	.4	.3
10.0			.4	.4	.6	.4	.4	.3
Frequency Sweep Rate (GHz/Sec)								
Resolution BW								
.02 MHz	.27	1.6 **						
.2	.27	2.0 **						
1.0		5.0 **	10	10	10	10	10	10
10.0			10	10	10	10	10	10
Frequency Dispersion (MHz) (Minimum Setting $F_1 - F_2$)	1	10	10	100	100	100	100	100
Noise Figure (dB)	4.5	6.5	7.5	11.0	11.0	15.0	15.0	15.0
Gain Stability (dB)	±0.5	±0.5	±0.5	±1.0	±1.0	±1.5	±2.0	±2.0
Frequency Accuracy (MHz)	.02	.02	.02	.02	.02	.02	.02	.02
Dynamic Range (dB)	65	65	65	65	60	60	50	50
Image Rejection (dB)	-65	-65	-65	-65	-65	-65	-65	-65
3d Order IM (dB)	-30	-30	-30	-30	-30	-30	-30	-30
Lo Radiation (dBm)	-80	-70	-70	-70	-70	-70	-70	-70
Data Output (MBIT/Sec) (Max)	1	1	1	1	:	1	1	1
High Power Protection (W - pulse)	2	2	1	1	1	.1	.1	.1
RF Signal Attenuation Control (dB)	20	20	20	20	20	20	20	20

* Frequency Stability: $\pm 2.5 \times 10^{-7}$

** Band B is sweep in three sub-bands 1.0-1.5, 1.5-2.0, 2.0-4.0

† Data for this chart were supplied by R. Lowman, Cutler-Hammer, Inc. (AIL), L.I., N.Y. (Ref. 7)

Controls for the receiver will be programmable or manually controlled by an operator. Normally the control function will be a computer which will probably operate in one of several standard modes. Receiver control parameters will be at least the following:

Frequency Band Select
Narrowbeam or Broadbeam or both
Sweep Bandwidth (F_1 and F_2)
Signal Amplitude Control
Receiver Sensitivity
Frequency Markers

Signal processing and signal identification by the receiver is expected to occur after the signal is down-converted to the last IF frequency. Data supplied on each detected signal will include at least the following:

Frequency
Signal Amplitude
Polarization
Time Tag
Antenna Position Data
Shuttle Position Data (supplied from Shuttle Computer)

Separate data outputs for a maximum of 1 Megabit/sec per channel will be provided for each band shown in Table 3-9. Receivers will have separate outputs to interface with an on-board computer, on-board display and outputs to be compiled for input to the Shuttle/Spacelab data transfer system through TDRS to the ground station.

As shown in Figure 3-2, some of the receiver equipment will be mounted on the upper antenna assembly. This will include the low noise receivers (LNA), down-converters to reduce the signals to $<$500 MHz, the frequency synthesizer and receiver protection controls. This equipment will be mounted on the assembly in enclosures near the appropriate antenna. Design of the assembly mounted equipment must consider exposure to full space environment.

3.5 SYSTEM CONTROL AND DATA PROCESSING

The EEE is basically a wideband receiver which has scanning antennas and low noise detectors that sweep the EEE frequency bands. Receiver sensitivity is set by antenna gain and receiver noise figure as described in Sections 3.3 and 3.4. Control of the receiver is also a key part of the experiment. This control involves receiver parameters such as sensitivity, frequency selection and protection against unwanted signals, other operational parameters for the antenna assembly such as azimuth and elevation scanning angles and antenna beamwidth selection, and control of data received.

Figure 3-10 shows a line diagram of the EEE data flow from signal detection at the antennas to the processing functions which send the data to ground realtime, display the data at the operation console and/or record the data for return to earth with the Shuttle. The key element for system control is the system computer which contains all the software to manage the experiment. Provision for manual control by the operator from the control console is included. Transfer of control signals and status monitor information through the rotary joint requires a single line remote control system, similar to the TT&C systems used in satellite control, except the control will be through an IF channel link.

Receiver controls on the antenna assembly are the beamwidth select at the receiver input, the signal attenuator for controlling receiver sensitivity and the limiters which provide receiver protection from large signal inputs in the frequency bands below 12 GHz. Frequency band selection is provided by local oscillator (LO) selection and IF channel blanking at the IF demultiplexer output. Each IF channel frequency is selected to allow signal multiplexing and transmission through the rotary joint with a minimum number of separate lines. As discussed previously, a separate channel is provided for the remote control subsystem. After incoming data are reduced to digital data streams, the data are compiled and routed to any or all of the three subsystems used for data management. Real-time data are compiled and sent through the Shuttle-TDRS link to ground. These same data are stored on-board for transport back to the earth with the Shuttle. A third parallel data stream is sent to the control console for display and use by the operator. (See Section 2.3)

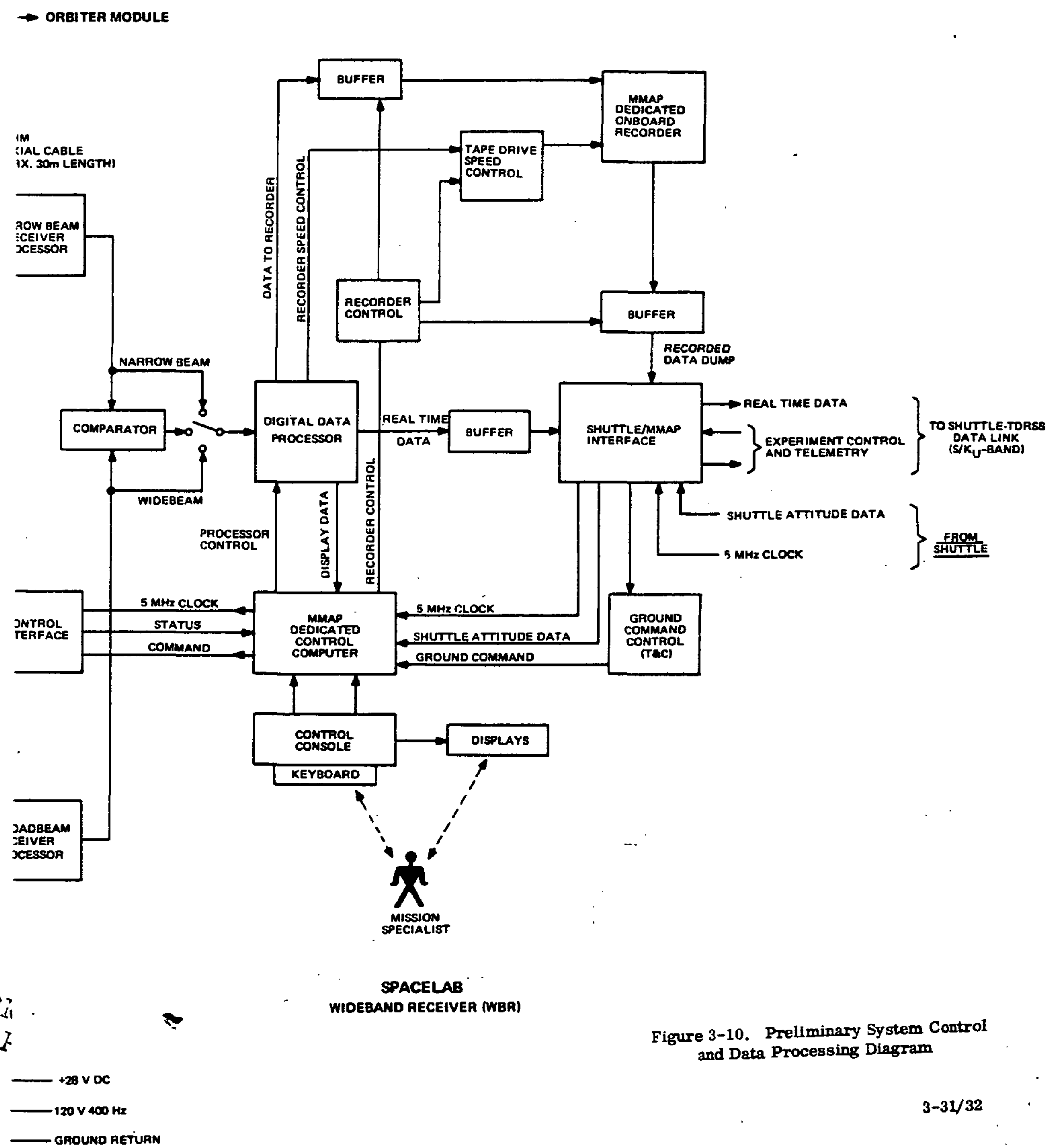

Figure 3-10. Preliminary System Control and Data Processing Diagram

All of the above controls are manipulated from the control console by the control computer in a selected/programmed operational mode or by manual selection by the operator. Data processing on-board will be a minimum, although specific Shuttle operation parameters such as time and Shuttle attitude information will be added to the data stream during operation.

Certain key parameters will have large effects on the data processing system. Signal characteristics, number of separate signals received, and frequency cell resolution essentially set the data rate for the recorder and TDRS links. The amount of viewing time for the mission sets the recorder storage capacity and the amount of link time required. Preliminary estimates of signal density indicate that 1 MBPS per channel will handle the busiest channel, the 1-2 GHz band, and that 1-5 x 10^9 Bits is the maximum storage needed in a 5-hour viewing time (6 day mission, CONUS viewing). These maximum limits on the data system are several orders of magnitude greater than needed for bands other than the 1-2 GHz band, especially in the higher frequency bands above 12 GHz. These parameters, however, provide some insight from which to size the recorder and the data capacity required on the Shuttle-TDRS link.

The Preliminary System Control and Data Processing diagram shown in Figure 3-10 provides an overview to the control and processing needed for the EEE. This diagram is intended to complement the system diagram shown in Section 3.2 and to illustrate some of the key factors and equipment in control and data processing for EEE.

SECTION 4
SHUTTLE INTERFACES

4.1 UPPER ANTENNA ASSEMBLY

The EEE upper antenna assembly described in Section 3.1 is to be mounted as shown in Figure 4-1. This arrangement allows for 360° azimuth scan and $\pm 80°$ elevation scan about nadir. The entire assembly will be stowed in the Shuttle bay using three standard pallets. During operation the Shuttle will be inverted to allow the antennas to view the earth. Figures 4-2 thru 4-6 show the assembly stowed and deployed on the Shuttle.

Controls for the upper antenna assembly will be brought through the rotary joint on slip-rings or through IF frequency coaxial rotary joints. IF signals from the antenna assembly will be multiplexed at IF frequencies and routed through the coaxial rotary joint to the Spacelab for processing.

A serious Shuttle interface problem may be caused by the rotating upper antenna assembly from the torque applied to the Shuttle by the assembly. The assembly is expected to weigh approximately 700 pounds and will rotate at varying speeds of 0-50°/sec. No possible solutions are proposed here, but the torque poses a limitation on the experiment because of potential assembly platform instability. This design problem requires further study.

4.2 ELECTRICAL INTERFACE

The slip-rings at the upper antenna assembly rotary joint pose limitations on the type of electrical interfaces to the assembly. All high voltages such as those required for TWT's must be generated on the assembly, frequency synthesizers must be self contained or controlled from a single fundamental frequency supplied through the rotary joint and all controls should be digital to be supplied through slip-rings. This puts a severe limitation on the number and type of controls for the antenna assembly. One solution is to code the command and control signals and operate using a single IF channel much in the same way as a TT&C system operates. This would allow a

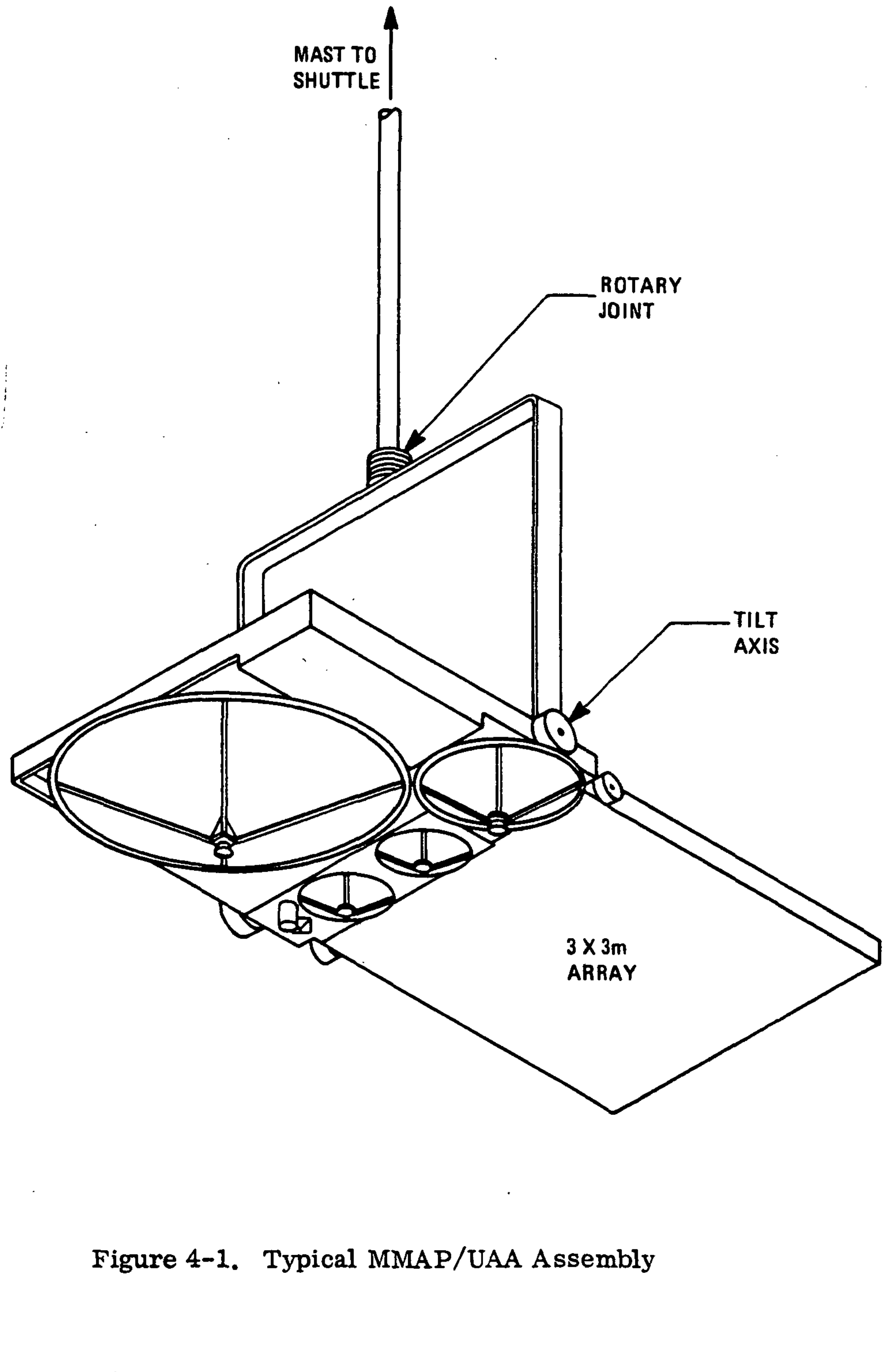

Figure 4-1. Typical MMAP/UAA Assembly

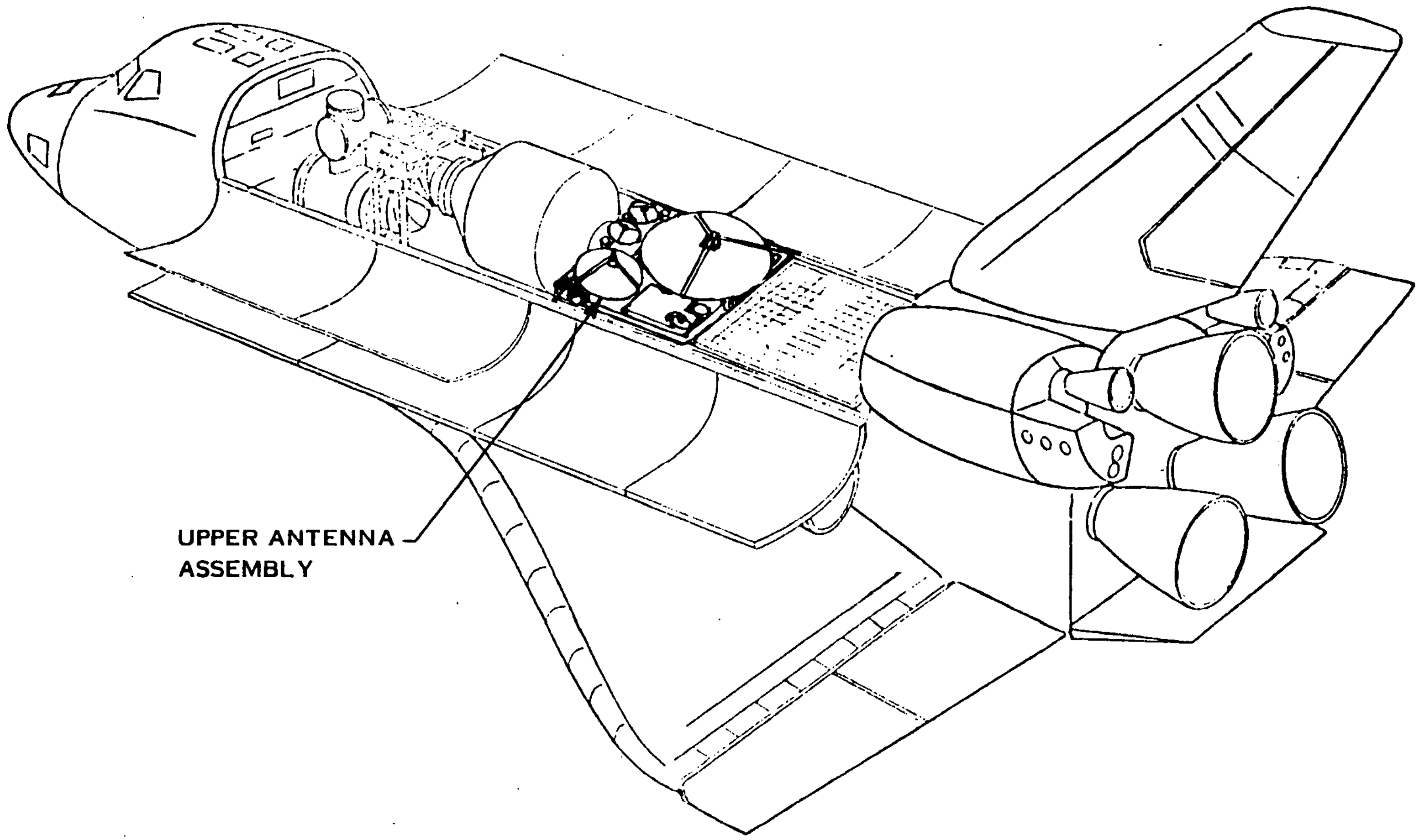

Figure 4-2. MMAP/UAA Stowed in the Shuttle Bay

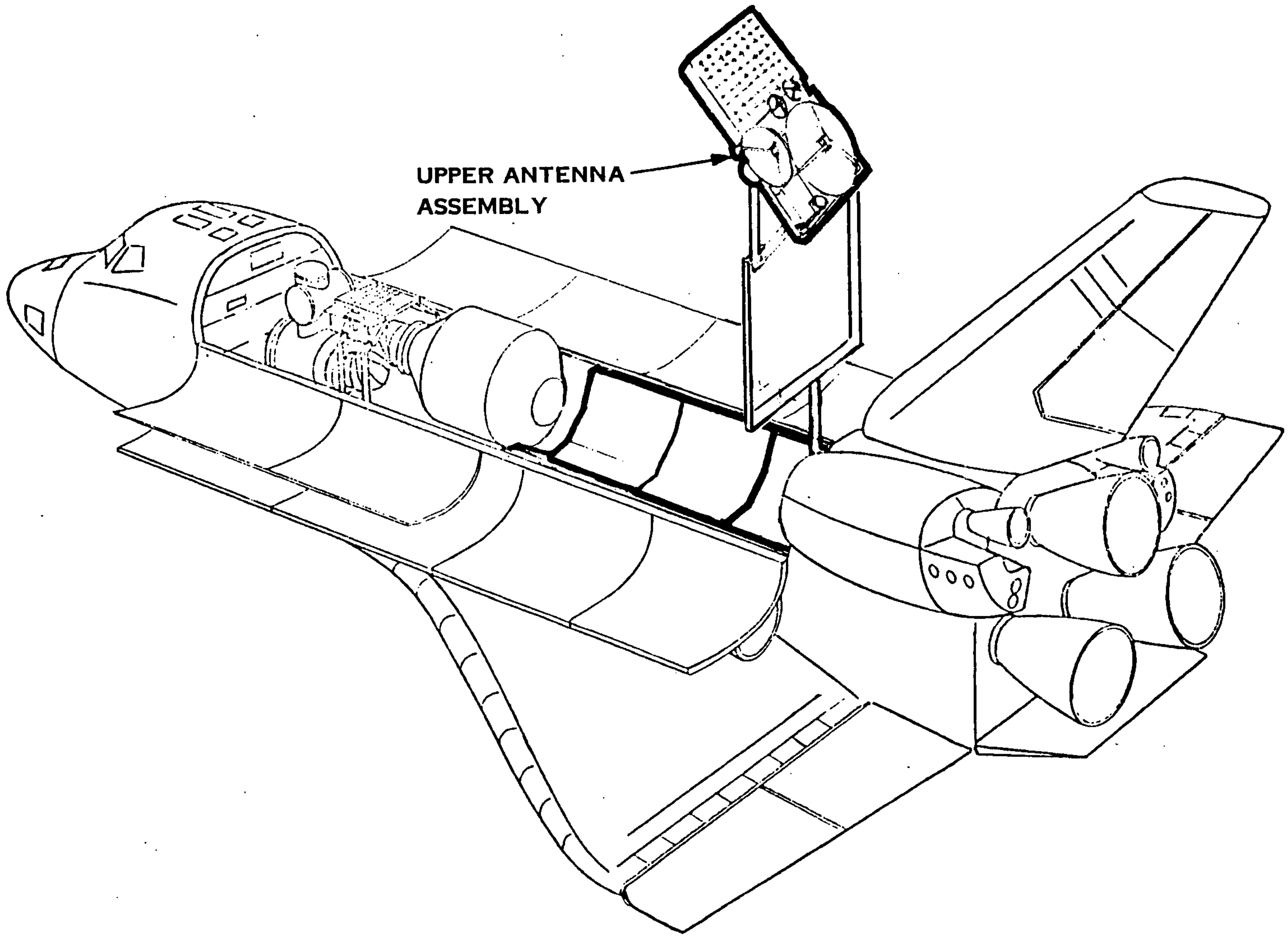

Figure 4-3. MMAP/UAA Deployed from the Shuttle

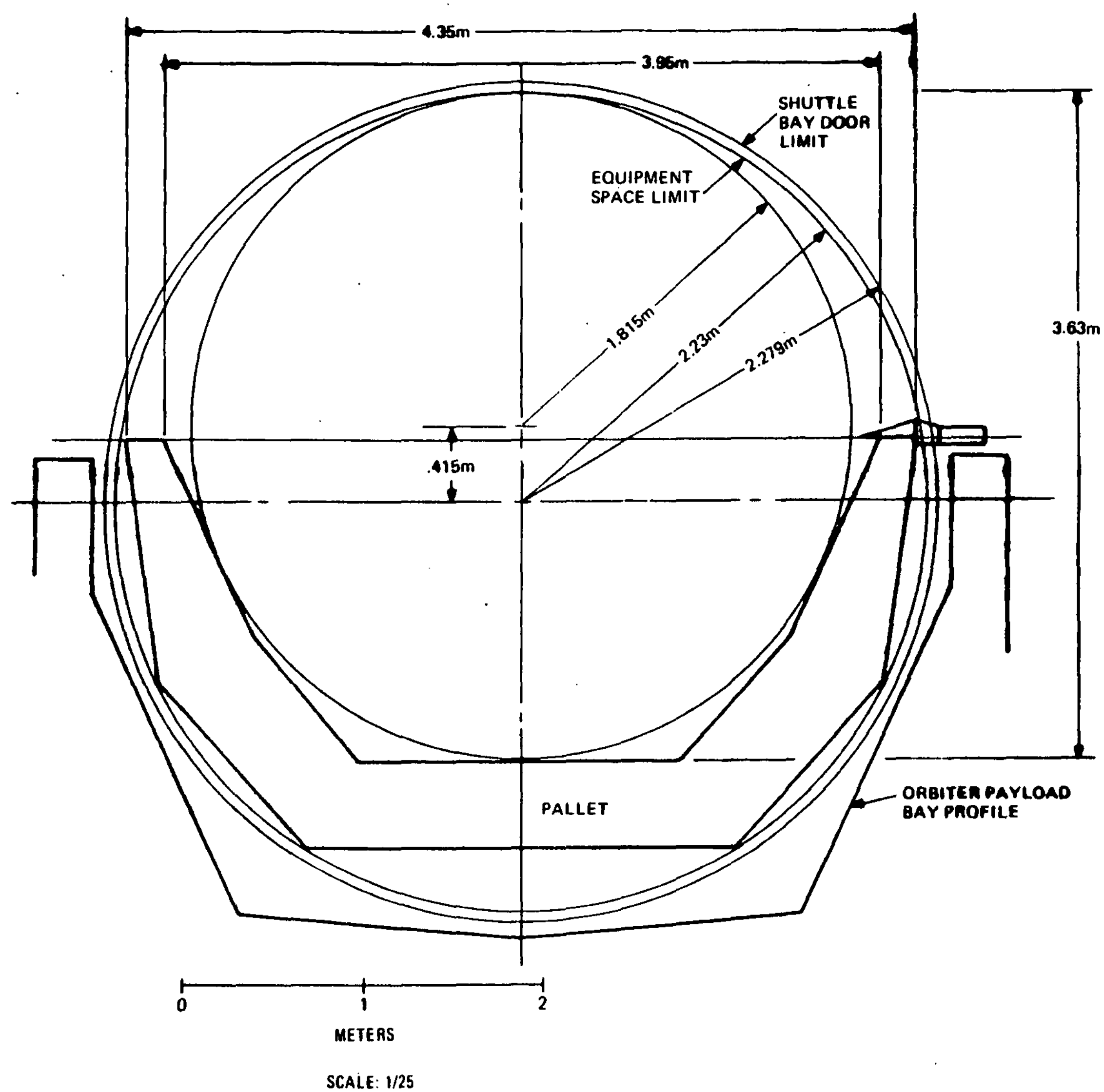

Figure 4-4. Shuttle Bay Cross-Section With Pallet

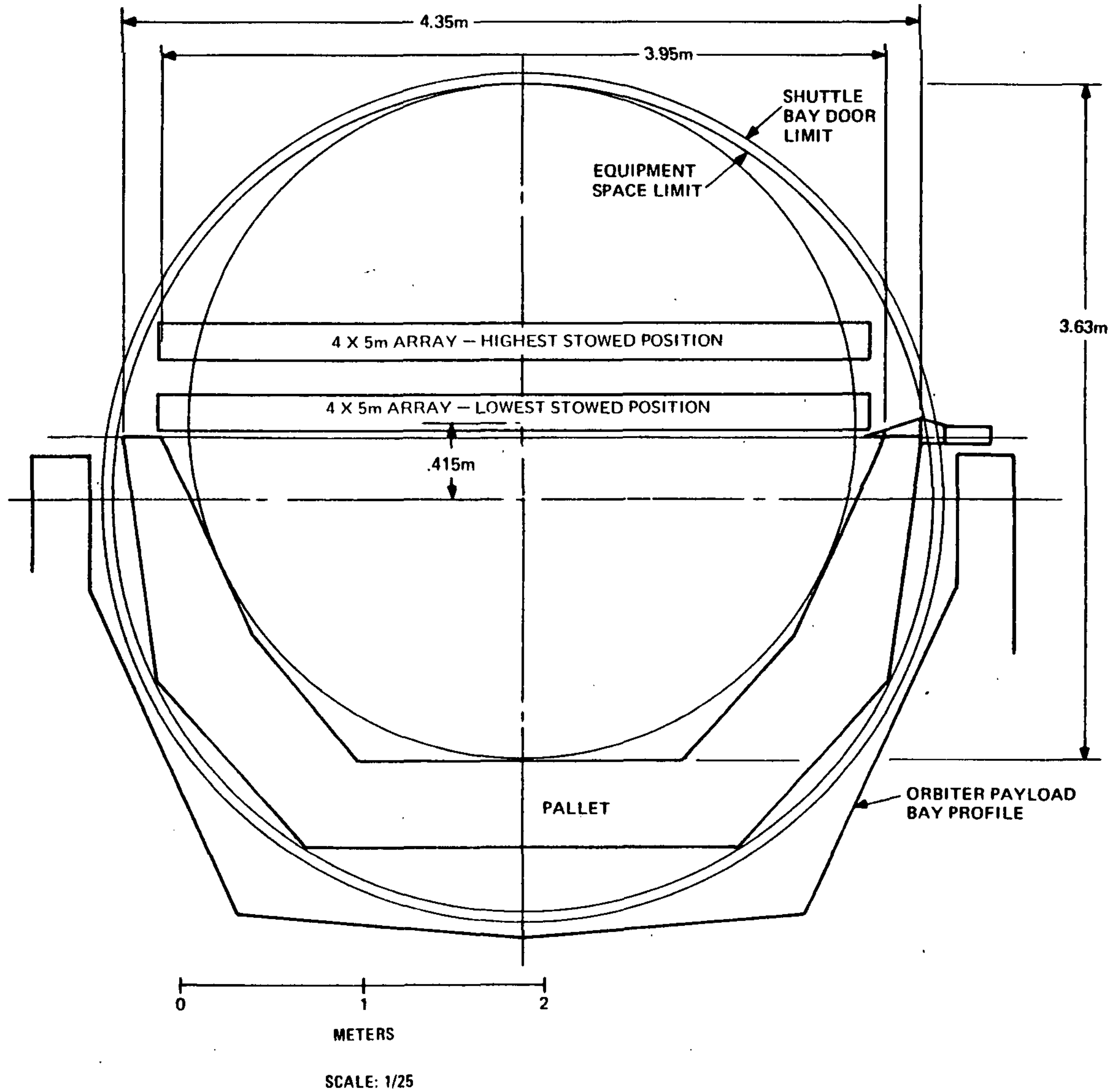

Figure 4-5. Cross-Section of Shuttle Bay Showing 4m x 5m Array Stowage Limits

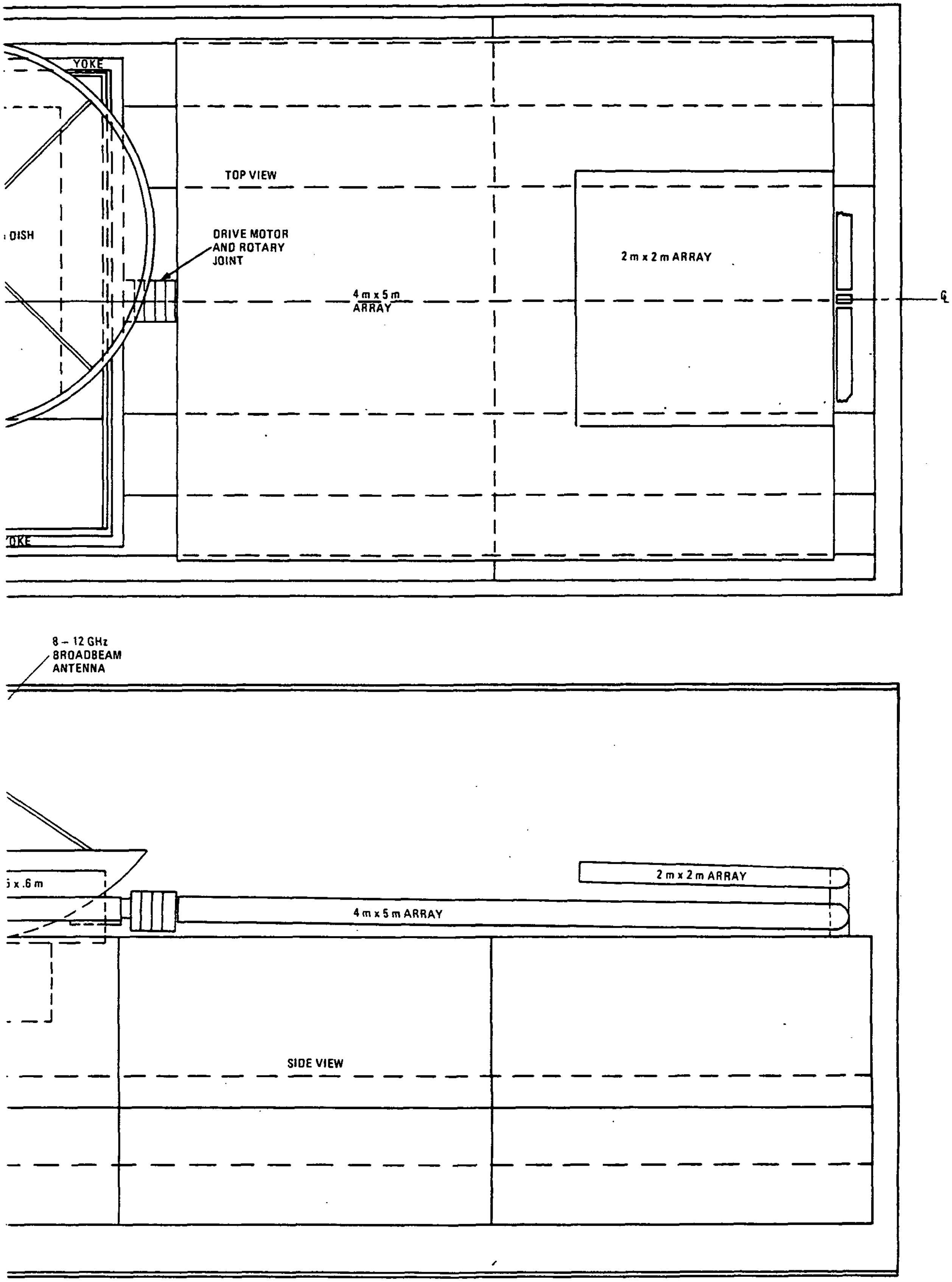

Figure 4-6. MMAP/EEE Typical Installation in Shuttle Bay

FOLDOUT FRAME 2

minimum mechanical connection through the rotary joint, but allows ample experiment control and monitoring. Some added complexity is required, however.

4.3 SYSTEM OPERATIONS INTERFACES

The EEE system requires certain operational procedures which reflect directly into the Shuttle and overall system operation. The EEE equipment should be checked before antenna deployment; some equipment may be repairable by changing modules if the equipment is in the Spacelab, but no maintenance of equipment in the bay is planned. All support activities must be checked, also, including communications with the earth via the TDRSS for real-time data transmission.

The MMAP experiments require the Shuttle to fly upside down before antenna deployment. As the antenna is positioned, the command and telemetry processes are initiated, and a continuing status indication displayed. Once deployed, the overall Shuttle schedule is begun.

The EEE system covers a large breadth of spectrum monitoring, and thus, is susceptible to various stray interference signals in the Shuttle as well as to a wide variety of terrestrial signals. Electromagnetic compatibility is a critical consideration for the MMAP mission which includes a large number of individual equipments to be operated simultaneously. A thorough analysis of harmonics, and second and third order mixing of frequencies, is a major concern in assessing MMAP performance, and in planning experiment operation. This design consideration requires further study and will be covered in the Final Report.

Data dissemination and storage is also a significant interface factor; some data will be retained on computers and processed after return to earth; some will be transferred to earth in realtime via TDRSS; and some will be transferred after being stored for an appropriate time when the data transfer links are available. Monitoring functions may have to be shared also, including the computer and man-operated equipment.

SECTION 5

SUMMARY

Results described in this report represent progress made in the first five months of the Phase B Definition Study for the Electromagnetic Environment Experiment. Most of the effort was directed toward designing the upper antenna assembly, antenna pattern and signal propagation studies, mission profiles, data processing and Shuttle interfaces. Integration of the EEE in the Microwave Multi-Applications Payload has been a major factor in defining the upper antenna assembly. The key output of this integration work is a summary of the MMAP experiments and proposed antennas; this summary is included as Appendix A.

The upper antenna assembly has been defined for the antenna and receiver basic components, and a preliminary physical configuration is included in this report. The assembly has been sized to fit into the Shuttle bay with other MMAP antennas using three pallets. Details of the assembly have not been completed, however. The assembly is composed of twelve antennas: one 3m x 3m UHF array, four parabolic reflectors varying in size from 3m to 0.7m, six broadbeam antennas, and a separate Ku-band monopulse tracking antenna system for the ARE and MMWC experiments.

Six scanning modes for the EEE antennas have evolved from the antenna scanning studies: circular conical scan, conical spiral scan, radial scan, a combination dual-beamwidth scan to be used in the conical spiral mode, sector scanning and manual operation. Footprints and radiation beam distortion caused by the propagation path and the spherical shape of the earth have been analyzed, and supporting data are included in this report.

Mission profile studies were completed for a 400 km height, 57^{o} inclination circular orbit. Studies of the proposed mission profile show that the flight profile follows a three-day repeat orbit; viewing times over the CONUS are in a twelve-hour time frame, occurring during the same time period each day. Total viewing time per day over the CONUS is approximately 50 minutes, with a mission total viewing time of about 5 hours.

Date processing requirements for MMAP/EEE have been analyzed for both on-board and ground processing. A preliminary system block diagram and software requirements are included. Shuttle interfaces have been studied primarily to determine what configuration the upper antenna assembly must have to stow in the three-pallet bay area.

Other work completed and reported here include an experiment frequency plan, a proposed antenna subsystem design, a proposed receiver design, and preliminary definition of system controls and data processing. As noted in the appropriate sections, some of the information included here was supplied by Hughes Aircraft Company (antennas) and Cutler Hammer Corporation (AIL) (receivers).

SECTION 6

WORK PLANNED FOR NEXT PERIOD

During the next reporting period, work will continue on definition and design of the upper antenna assembly, Shuttle interfaces for the antenna assembly, antenna pattern and signal propagation studies and mission profiles. The primary effort in the payload definition will be to complete the Performance Specifications and prepare Level A and B Payload Descriptions. In summary, work will be directed in the following areas toward completing of the EEE program:

Work Started First Period	
x	- Complete design performance specifications for the EEE flight hardware
x	- Prepare Level A and B Payload Descriptions
x	- Define Shuttle/Spacelab interfaces
x	- Define two- and ten-year mission profiles for EEE
x	- Define electrical/mechanical and space environmental specifications for EEE flight hardware
x	- Define reliability and quality assurance (R&QA) specifications
	- Define EEE "free-flyer" experiments for monitoring specific frequency bands
	- Define a standard electronics package module that can be tested on any Shuttle/Spacelab mission

SECTION 7

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VIII	Mission Operations
IX	Ground Operations
X	Flight and Ground Specifications
XI	Crew Operations
XII	Integrated Logistics Requirements
XIV	Space Shuttle System Payload Accommodations
XVIII	Computer Systems Software

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APPENDIX A

MMAP/EEE

ANTENNA BASELINE

NOVEMBER 26, 1975

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GODDARD SPACE CENTER

COMMENTS SHOULD BE ADDRESSED TO:

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Table A-1. Shuttle/Spacelab
Microwave Multi-Applications Payload *Experiments* (MMAP)

Experiments Sharing MMAP UPPER ANTENNA ASSEMBLY		Experimenter
1.	Electromagnetic Environment Experiment (EEE)	R. Taylor
2.	Millimeter Wave Communications Experiment (MMWC)	L. Ippolito
3.	Surface Spectrum Radar (SSR) Experiment	T. Walton
4.	Antenna Range Experiment (ARE)	R. Taylor/ A. Durham
5.	Data Collection with Multibeam (DCMB)	L. Dod
6.	Meteorological Radar (METRAD) Experiment	J. Eckerman
Other MMAP Experiments:		
7.	MW Imaging Spectrometer Experiment (MWISE)	L. King
8.	Atmospheric and Oceanographic Imaging Radiometer (A&O R/M)	J. Shiue
9.	Soil Moisture and Salinity Radiometer (SMS R/M)	J. Shiue
10.	Adaptive Multi-Beam Antenna (AMBA) Experiment	S. Durrani
11.	Attitude/Position Location Interferometer (I/F)	A. Kampinsky
12.	Cooperative Surveillance Spacelab Radar (CSSR)	D. Brandel
13.	NAVSTAR/GPS (GPS)	J. Turkiewicz

Table A-2. MMAP/EEE Antenna Baseline

Antenna	Experiment (No.)[1]	Freq. - (T-R GHz)	Polarization
3m x 3m Array	EEE (1) DCMB (5)	0.4 - 0.5 (R) 0.4 (R)	RHCP RHCP
3m Dish	EEE (1) SSR (3) ARE (4) METRAD (6)	1-12 (R) 1.25 (T-R), 10 (T-R) 2.2-2.3 (T) [3-6 (T-R)]	RHCP/Linear Linear RHCP RHCP
1.5m Dish	EEE (1) ARE (4) METRAD (6)	12-26 (R) [13-14 (T)] [15-20 (T-R)]	RHCP/Linear RHCP RHCP
0.7m Dish #1	EEE (1) MMWC (2)	26-40 (R) 30 (R-Only)	RHCP/Linear Simultaneous RHCP/LHCP
0.7m Dish #2	MMWC (2)	20 (T-Only)	Simultaneous RHCP/LHCP
Broadbeam #1	EEE (1)	1-4 (R)	RHCP/Linear
Broadbeam #2	EEE (1)	4-8 (R)	RHCP/Linear
Broadbeam #3	EEE (1)	8-12 (R)	RHCP/Linear
Broadbeam #4	EEE (1)	12-18 (R)	RHCP/Linear
Broadbeam #5	EEE (1)	18-26 (R)	RHCP/Linear
Broadbeam #6	EEE (1)	26-40 GHz (R)	RHCP/Linear
Autotrack-Corr. Horn	MMWC (2) - Slave ARE (4)	15-16 (R)	RHCP/Linear
Other MMAP Experiments			
0.3m Dish	MWISE (7)	94 (R)	Linear V & H
Electronic Scanning (Antenna not specified)	A&O R/M (8)	18, 22, 36 (R)	Fast Scan Linear V&H
2m x 2m Array	AMBA (10) SMS R/M (9)	1.5 (T), 1.6 (R) 1.4 (R)	RHCP/LHCP Linear H Only
0.3m x 0.3m Array	AMBA (10)	12 (T), 14 (R)	RHCP/LCHP
4m x 5m Array	METRAD (6) CSSR (12)	10 (T-R) 10 (T-R)	TBD TBD
Interferometer #1	GPS (13)	1.2 (R)	TBD
Interferometer #2	METRAD (6)	10 (R)	TBD
OMNI	NAVSTAR-GPS (13)	1.2 (R)	TBD

[1] Experiment Titles Corresponding to Numbers Are Shown in Table A-1

[ ] Exact Frequency TBD Later

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